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ABSTRACT

The United States contribution to the International Biological Program, which aims to understand more clearly the interrelationships within ecosystems, is centered on multidisciplinary research programs investigating the biological basis of ecological productivity and human welfare. Integrated research programs have been established for the analysis of ecoystems; the study of biological productivity in coastal upwelling ecosystems; the provision of data needed for marine mammal management; the comparison of different ecosystems with similar physical features; the population genetics of South American Indians; the biology of high altitude human populations; and the study of circumpolar peoples. Co-ordinated research projects have been established on the ecology of nitrogen; the biological control of insect pests; aerobiology; phenology; ecosystem conservation; the conservation of plant genetic materials; the biosocial adaptation of migrant and urban human populations; human nutritional adaptation; and human biological rhythms. For each program there are statements of the research objectives, a summary of progress, a list of publications, and the names of participants. (AL)

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RESEARCH PROGRAMS CONSTITUTING U.S. PARTICIPATION IN THE INTERNATIONAL BIOLOGICAL PROGRAM

REPORT NO. 4 OF THE U.S. NATIONAL COMMITTEE FOR THE INTERNATIONAL BIOLOGICAL PROGRAM

NATIONAL ACADEMY OF SCIENCES

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U.S. National Committee for the International Biological Program
Division of Biology and Agriculture
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1971

PREFACE

This report summarizes progress in organizing the research programs that constitute U.S. participation in the International Biological Program and describes the status of research within these multidisciplinary studies. It follows a report entitled *Research Studies Constituting the U.S. Contribution to the International Biological Program*, which was published in two parts. It differs from the previous report in that it is devoted exclusively to the research programs. The earlier reports included projects judged to be "IBP-related"; files and indices of these are maintained in the office of the U.S. National Committee.

International coordination is accomplished through the Program Directors and through the Executive Committee of the U.S. National Committee for the IBP. Those interested in the work of a given program are encouraged to communicate with the appropriate Director.

Support for the research is provided directly to the individual programs by a number of federal agencies: National Science Foundation, Department of Agriculture, Atomic Energy Commission, Smithsonian Institution, Department of the Interior, Department of Commerce, Department of Defense, Department of Health, Education, and Welfare, and National Aeronautics and Space Administration. Several private foundations and industrial organizations provide support for components of the programs.

The Executive Committee of the U.S. National Committee for the IBP acknowledges with gratitude the efforts of the Program Directors and their colleagues and of the scientists in other countries who have contributed in many ways to the development of the research effort.

Executive Committee of the U.S.
National Committee for the IBP

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Introduction

During the discussions from which the International Biological Program emerged, it was recognized that multidisciplinary approaches appropriate to the IBP should be encouraged and that these studies would almost certainly continue beyond the formal life of the IBP.

The overall goal is to understand more clearly the interrelationships within and among ecosystems by:

- Advancing knowledge of the genetic adaptations of man.
- Advancing knowledge of the physiological and behavorial adaptations of man.
- Formulating a basis for better understanding the interactions of components of representative biological systems.
- Exploiting the understanding of biological systems to the end of increasing biological productivity.
- Providing bases for predicting the consequences of environmental stresses, whether man-made or natural.
- Enhancing our ability to better manage our natural resources.

The U.S. response to the challenge of the IBP—to elucidate the biological basis of productivity and human welfare—is centered on the multidisciplinary research programs. Two types of research programs have been organized: integrated research programs and coordinated research programs.

Each of the integrated research programs has:

- Demonstrated that it is necessary to integrate a number of research projects if the scientific goals of the program are to be realized.
- Posed questions of appreciable scientific significance, thus giving coherence and direction to the suite of research projects in the program.
- Devised a system for coordination and rapid exchange of information and data so that as work proceeds each participant will profit from the efforts of others.
- Provided a means of synthesizing the results of included projects, thus enhancing the total achievement.

Coordinated research programs are an association of related research that when taken collectively make a contribution to the field. The emphasis is on coordination of closely related, usually ongoing, research.

INTEGRATED RESEARCH PROGRAMS

3/4

ENVIRONMENTAL COMPONENT

Analysis of Ecosystems

The analysis-of-ecosystems program is designed to provide basic information on ecological systems through a comparative study of six major habitat types (biomes). This knowledge will be useful for solving problems of biological production, resource management, and environmental quality.

Past studies have analyzed a number of aspects of ecosystems, including kinds of organisms present, their abundance, their arrangement in space, and their food; flow of energy through the system; and cycling of nutrients. Although the data describe *what* happens, they do not explain *why* it happens—why so many species live together, why so much plant production is not eaten by animals, why mortality rates are so high among most herbivores, or why systems persist year after year although individual population levels fluctuate between extremes. Finding the explanations requires more than analysis. It requires a synthesis of information into working models describing the structure and functions of whole ecosystems.

We know that green plants, herbivores, predators, and decomposers are all interconnected and that production at one level may be greatly influenced by activity in other parts of the system. However, little is known about the processes. Studies with mathematical models of systems suggest that interrelations may be much more pervasive than they are now believed to be.

Strong emphasis is being placed on the physical and chemical factors of the environment since the ecosystem is the combined result of interactions among these factors and biological factors. Such fields as botany, zoology, microbiology, soil science, geology, hydrology, meteorology, and limnology are being brought together. Equally important to the combined efforts are several fields of engineering, particularly systems engineering.

Understanding the functioning of the ecosystems will provide a more valid basis for management of renewable resources. All management programs for renewable resources contain ecological concepts that attempt to describe the response of the managed population to its management. At present, the ecological theory that serves this function relates to individuals or to populations, not to systems as wholes. This limited approach is reasonably satisfactory so long as the goals of management are centered on single species or populations.

The multiple use of natural renewable resources is increasing steadily, however, often combining timber production, hunting, fishing, and recreation; management programs attempt to maximize these uses simultaneously. The contribution of the analysis-of-ecosystems program to resource management rests in the manipulation planned in ecological systems and the production data that will result.

The quality of the environment is another facet of this program. Some types of environmental deterioration are evident to the most casual observer; others of equal or even greater importance are less visible and exert their effects over decades. As examples of this, one might list the thinning of the soil, the decreasing quality of water supplies, the increasing number of pest species, the dense algal blooms in lakes, the decreasing number of game fish, and other changes in the number and abundance of native species.

Many problems of environmental deterioration cannot be understood without a profound knowledge of ecological systems. The relationship between cause and effect of deterioration in a system is often difficult to establish. Usually the cause lies in one part of the system and the response is seen in another. Finding the relationship would be greatly facilitated by a complete understanding of ecosystem processes and their couplings.

OBJECTIVES

The stated goals of the analysis-of-ecosystems program are:

- To establish a scientific base for programs to maintain or improve environmental quality
- To derive broad principles of ecosystem structure and function through an integration of the results of six biome studies
- To relate these principles to characteristics of ecosystems (e. g., persistence, stability, maturity, and diversity)

- To develop and refine a generalized adaptable simulation model suitable for use in planning studies for new development projects

Each of the biome studies (grasslands, deciduous forests, coniferous forests, desert, tundra, and tropical forests) includes among its objectives:

- To relate productivity, nutrient cycling, energy flow, and other characteristics of ecosystems in a set of distinct environments
- To determine the driving forces, the processes causing transfers of matter and energy among components, the nonconcentration characteristics, and the controlling variables in each biome
- To determine the ecosystem response to natural and man-induced stresses appropriate to each biome (e.g., large herbivores in the grasslands biome, extreme weather patterns in the desert biome, periodic fluctuations of rodent populations in the tundra biome, commercial use of timber in the coniferous forests biome, urbanization in the deciduous forests biome, and nutrient retention in the wet tropical forests biome)
- To understand the land-water interactions characteristic of each biome (e. g., prairie ponds and reservoirs in the grasslands biome, the abundance of shallow waters in the tundra biome, springs and temporary waters in the desert biome, river systems with anadromous fish populations in the coniferous forests biome, pollution and eutrophication in the deciduous forests biome, and large river systems in the tropical forests biome)
- To synthesize the results of these and previous studies into predictive models showing temporal and spatial variation, effects of pollutants and of exploitation, stability, and other ecosystem characteristics necessary for resource management in each biome

RESEARCH PLANS

The analysis-of-ecosystems program consists of a central program and studies of ecosystems in six biomes. Most Americans live in and extract the major portion of their food and fiber from three of these biomes: grasslands, deciduous forests, and coniferous forests. These biomes extend over in the middle range of temperature and precipitation; the others (tundra, desert, and tropical forests) were selected because they encompass extreme environmental conditions.

The central program develops the ecosystem studies, ensures comparability of studies, and provides the synthesis of results needed to develop ecological principles based on comparisons of results from the six biomes.

The ecosystem studies make extensive use of systems analysis, which includes the orderly and logical organization of data and development of mathematical and simulation models. The goal is to produce functional models that serve for the computer simulation of ecosystem processes. In systems analysis, an ecosystem is regarded as a number of subsystems. Since a subsystem is simpler than the system as a whole, this smaller unit is more susceptible to analytical treatment. A submodel of each subsystem can be built, and the submodels can then be synthesized into a model of the whole. In ecology, the complexities of the whole system are far greater than those with which most other scientists have had to deal, and the methods of classical mathematics that physical scientists can use to combine separate studies into a whole have not been applicable. The general availability of electronic computers has made the systems analysis approach in ecology a practical possibility.

Two types of field studies are required: process studies and validation studies. The purpose of process studies is to describe the rate of change of each ecosystem component in terms of the present state of this component and all other components of the ecosystem. Results of the process studies are used to construct the ecosystem model. To understand processes, we must do more than measure them. If a single system were analyzed completely, there would not be any information on factors that produced the observed results and there would not be any means of predicting what would happen if system components were altered. Developing this additional information requires that processes be observed as they change in response to manipulation of causal factors and that both the causal factors and the process output be monitored. Various system manipulations are included in each of the biome programs.

Since the ecosystem components are too numerous to be studied individually, many of them must be combined for study. This procedure may lead to inaccurate models. Hence, the models must be checked against actual field conditions. Studies that gather data to check the ecosystem models are called validation studies.

The value of the ecosystem models, developed by the biome studies, depends on how widely such models can be applied. It is hoped that one model, with different sets of components and parameters, will apply to all variations of a given biome. The permissible range of generalization for the simulation model will be determined by the validation studies against which it has been checked. If the validation sites are a representative sample of the biome and if the simulation model has been satisfactorily validated against them, then the model's range of applicability can be regarded as covering the biome as a whole.

RESEARCH METHODS AND PROGRESS

The progress achieved in the central program is best measured by the progress achieved in the biome studies

described in the sections that follow. Because funds were obtained at different times, the studies are in different stages of development, and synthesis of results has not yet been possible.

Although the studies are in different stages, efforts are being made to coordinate them:

- Subjects related to all six studies are discussed at interbiome meetings, which are attended by specialists from various fields. Matters discussed include comparability of methods, new techniques, and the kinds of studies needed in the context of the total program.
- The need to expedite communication has been recognized. First, investigators must be kept informed about progress of the studies. This need is met by arranging frequent meetings for investigators. Second, research results must be disseminated rapidly. An interbiome committee has made significant progress in developing a system for storing and retrieving information.
- Interbiome groups are engaged in coordinating activities having to do with aquatic microbiology, meteorology, modeling, and primary production.

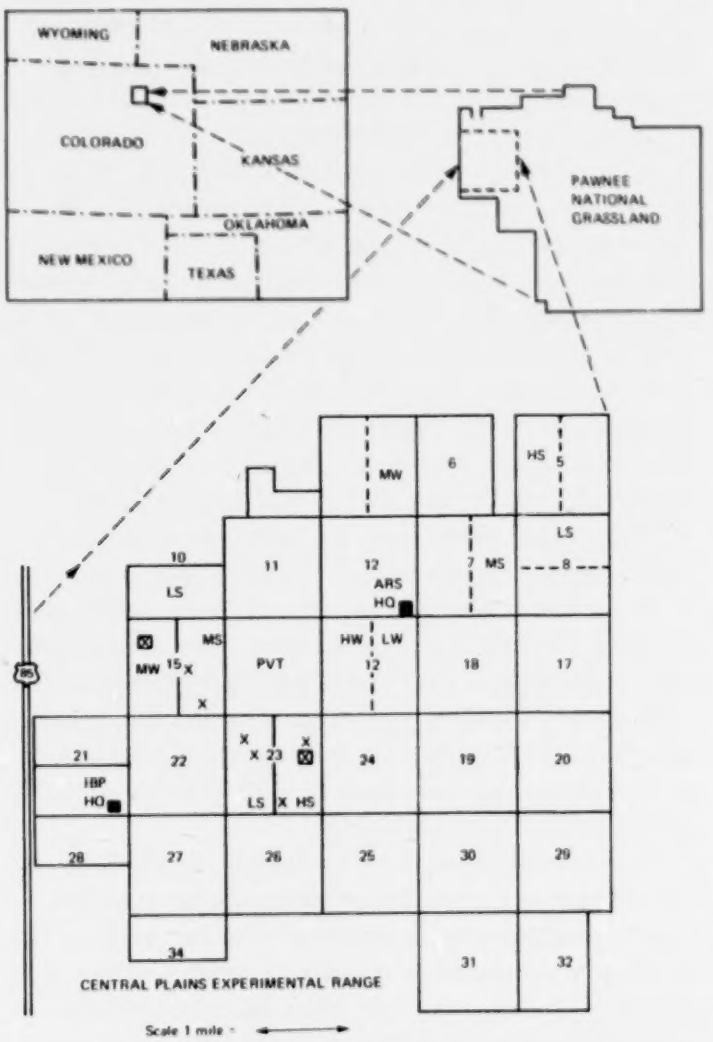

FIGURE 1 Pawnee Site. H = heavy herbivore treatment; L = light herbivore treatment; M = moderate herbivore treatment; S = summer herbivore treatment; W = winter herbivore treatment; PVT = private land for aquatic and telemetry study; X = microwatershed; X in a square = enclosed microwatershed.

GRASSLANDS BIOME

The grasslands biome in the United States includes annual, desert, shortgrass, mixed prairie, tallgrass, Palouse, and mountain grasslands. The strategy adopted for investigating the physical and functional variations within this biome called for two kinds of studies: (1) Detailed process studies are conducted at a single "intensive site." (2) Other process studies and validation studies are conducted in a network of sites.

The intensive site, known as the Pawnee Site, is in north-central Colorado (Figure 1). Field investigations began there in the middle of 1968. The comprehensive network sites are located throughout the grasslands (Figures 2 and 3). Field investigations began there early in 1970. The general characteristics of these sites are given in Table 1. Detailed descriptions of the sites are found in Technical Reports 1 and 36-45 (see Appendix A, p. 14).

Our broad research objectives are to study various natural and man-stressed grassland ecosystems (1) to determine the interrelationships of structure and function, (2)

FIGURE 2 Location of comprehensive network sites in relation to the Pawnee Site (Colorado), the Matador Site (Saskatchewan, Canada), and the Campana Site (Chihuahua, Mexico). ★ = first order (intensive); ● = second order; ■ = third order; □ = proposed; ○ = potential; ☆ = other North American grassland IBP sites.

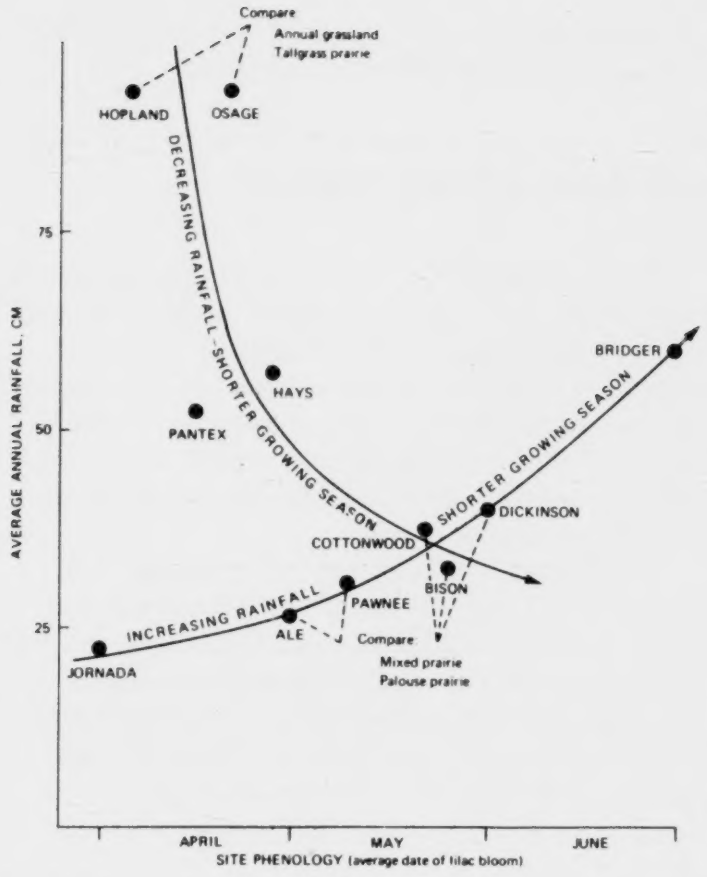

FIGURE 3 Environmental gradients of comprehensive network sites.

to determine the variability and magnitude of rates of energy flow and nutrient cycling, and (3) to encompass these parameters and variables in an overall systems model. We have used a systems-analysis approach in our research, systematically isolating and examining ecosystems and their components (see Technical Report 32). We ask the following general questions:

1. What are the driving forces that make grassland ecosystems operate?
2. What are the major and minor components of grassland ecosystems, and what are the changes in magnitude of these components over time?
3. What are the important families or groups of processes that cause the interaction or linking of the components of the ecosystem to one another?

We must also know the changes in certain parameters of ecosystems over time, and we must know how plant, animal, and microbial community or social interactions affect processes. Furthermore, we include manipulations or treatments by man to determine their influence on processes and components.

RESEARCH PLANS

The research objectives, which are broad and diverse, made it necessary to design experiments with great care. We observe and measure the responses of the system to different sets of stresses. From detailed analyses of the results of the experiments we derive information about the effects of driving forces, components, and processes on one another. Further, we examine how these are related to structure and to community or social interactions.

We have designed a variety of initial models of total grassland systems or of their components to provide a focus for our research efforts. These models are mathematical expressions of various degrees of complexity and resolution, and many include probabilistic measurements. Much of our analysis effort has been devoted to developing an overall scheme in which to frame our individual models. Eventually, we translate the mathematical expressions into computer languages to permit simulation and optimization analyses to be made. From such analyses we expect to obtain a basis for redesigning our experiments.

At the Pawnee Site, a shortgrass prairie, we have established a large interdisciplinary team to measure as many as possible of the compartments, driving forces, parameters, and control variables in a set of stressed grasslands. The nature of the research determines the size of the areas studied. Examples include (1) detailed soil moisture dynamics research in a weighing lysimeter 3 m in diameter, (2) eight 0.5-hectare microwatersheds, (3) 14 1-hectare stress treatment plots, (4) four 10-hectare pastures used for large-mammal comparative-diet studies, (5) three 128-hectare pastures used for domestic-animal grazing studies, and (6) areas of over 1,000 hectares for studies involving widely ranging animals (e.g., jackrabbits and coyotes), and many birds. Under memoranda of agreement with the U.S. Department of Agriculture, additional areas for research are available on the 6,000-hectare Central Plains Experimental Range and the 44,000-hectare western part of the Pawnee National Grassland (see Figure 1 and Technical Report 8).

The major stressing or perturbation treatment is that of herbivory, imposed by more than 30 years of known zero, light, moderate, or heavy grazing by domestic animals. Moisture and nutrient stresses are also imposed on selected plots. We plan to impose additional stresses, such as replacement or elimination of different biotic components of the community.

In the comprehensive network sites, including all major types of United States grasslands, we assemble smaller interdisciplinary teams to focus primarily on two treatments: ungrazed by domestic animals and heavily grazed by domestic animals. Thus, the comprehensive network program includes a subset of treatments found in the Pawnee Site studies. Measurements are made in the network according to a plan developed and agreed upon by the research participants (see Technical Report 35).

In both the Pawnee Site and the comprehensive net-

TABLE 1 Characteristics of Comprehensive Network Sites and Intensive Site

Site	Elevation (m)	Major Vegetation	Grassland Type	Phenology (lilac bloom)	Annual ppt (cm)	Soil
Comprehensive network sites						
Arid lands ecology site	520	Agropyron spicatum Stipa comata	Palouse	May 1	30	glaciofluvial and aeolian
Bison	980	Festuca scabrella Festuca idahoensis	Palouse	May 20	33	Chernozem
Bridger	2,320	Festuca idahoensis Agropyron subsecundum	Mountain	July 1	61	Chernozem
Cottonwood	850	Agropyron smithii Stipa viridula	Mixed	May 20	38	silty clay
Dickinson	850	Stipa comata Bouteloua gracilis	Mixed	May 30	41	Flasher loamy fine sand
Hays	610	Andropogon scoparius Andropogon gerardi	Mixed	April 25	58	Armo, immature, rocky
Hopland	300	Avena fatua Hordeum jubatum	Annual	April 5	94	Prairie
Jornada	1,340	Bouteloua eriopoda Sporobolus flexuosus	Desert	April 1	23	alluvial fill
Osage	380	Andropogon gerardi Panicum virgatum	Tallgrass	April 20	94	Labette, silty clay
Pantex	1,090	Bouteloua gracilis Aristida longiseta	Shortgrass	April 15	53	Pullman, silty clay loam
Intensive site	1,430	Bouteloua gracilis Buchloe dactyloides	Shortgrass	May 10	30	alluvial plains, sandy clay loams

work sites, teams measure the abiotic components of the system and the biotic factors. The difference is primarily one of extent, the effort being more intense on the Pawnee Site. Analysis of the results of the Pawnee Site studies provides us with forms of equations in simulation and optimization models and means to estimate coefficients in those equations. We can construct similar but simplified models for the comprehensive network site studies. We can then compare results obtained from running these different models, test them against the variations of physical and climatic characteristics of the different grassland sites, and examine differences in their biotic components. This will lead to ecological generalizations about grasslands that we expect will be valuable to natural resource management.

The Natural Resource Ecology Laboratory at Colorado State University, Fort Collins, manages and coordinates the research. George M. Van Dyne is Grasslands Biome Director. The organizational structure is shown in the following list. Activities at the first level (Administration, Services, etc.) are phases; each has a director. Those at the second level are areas; each has a manager.

A. Administration (R. Gerald Wright and Peter T. Haug)
   1. Administrative assistance
   2. Secretarial assistance
   3. Bookkeeping assistance
   4. Typing assistance
B. Services (George M. Van Dyne)
   1. Data processing and analysis (Lewis J. Bledsoe and Francis Swartzman)
   2. Sample processing and analysis (Charles L. Streeter)
C. Scientific coordination and information (George M. Van Dyne)
   1. Scientific coordination (Dennis H. Knight)
   2. Information dissemination (R. Gerald Wright and Peter T. Haug)
   3. Meetings (R. Gerald Wright and Peter T. Haug)
D. Systems analysis (George M. Van Dyne)
   1. Grasslands seminar (Herbert G. Fisser)
   2. Mathematical modeling (George M. Van Dyne, Donald A. Jameson, Norman R. French, Gordon Swartzman, Robert C. Francis, Lewis J. Bledsoe, and subject-matter specialists)
E. Pawnee Site project (Donald A. Jameson)
   1. Facilities, equipment, reference collections (Robert E. Bement, Freeman M. Smith, and William M. Klein)
   2. Remote sensing (Lee D. Miller)
   3. Abiotic-atmospheric (Robert D. Burman)

4. Abiotic-edaphic (John O. Reuss)
5. Producers (William H. Moir)
6. Consumers (Kirvin L. Knox)
7. Decomposers (Kenneth G. Doxtader)
8. Aquatic (James W. Lavelle)

F. Comprehensive program (Norman R. French)
1. Network Studies (Norman R. French)
2. Process Studies (Norman R. French)

G. International cooperation (George M. Van Dyne)

The central biome office does some purchasing; provides budgeting, administrative, and chemical analysis services; and supervises scientific coordination and information, preparation of manuscripts and reports, data processing, and systems analysis (see Technical Reports 24 and 34). The Pawnee Site operates a field dormitory, kitchen, dining hall, laboratory, and sample processing facility.

Research investigations are grouped according to driving forces and trophic levels. The driving forces include the abiotic components of the environment. The trophic levels are producers, consumers, and decomposers. Scientific coordinators, subject-matter specialists, and interdisciplinary specialists help maintain communication and coordination among these research groups.

A list of participants, which includes addresses and areas of specialization, is given in Appendix C (p. 18). (See Technical Report 24 for detailed vitae and descriptions of work.) Participants contract with the Biome Director to undertake specific projects. In 1969–1970, about 35 scientists were working on the Pawnee Site, about 35 on the comprehensive network sites (some work on more than one site), and 8 in the central program. Most of the scientists receive support from the grassland program for only a few months each year. About 70 graduate students are working in the program.

RESEARCH METHODS AND PROGRESS

Research progress is reported for the Pawnee Site, comprehensive network sites, modeling studies, and interdisciplinary research coordination.

PAWNEE SITE

Research progress at the intensive site is most logically covered in the direction of energy flow: abiotic, producer, consumer, and decomposer. Details are given in Technical Reports 2, 3, 5-7, 9-23, 26-31, 33, 49, and 50-55.

The results of the abiotic studies have been used to characterize the physical environment. Analysis of historical weather data, including temperature, precipitation, and wind, has suggested that temperature has a strong seasonal component and lags behind total daily radiation about 1 month. This lag is directly related to the number of cloudy days in June that have the effect of lowering the average daily temperature for that month. For simulation purposes, temperatures can be represented as departures from the season component, and the departures can be associated with rainfall periods.

Precipitation analysis has revealed that regional variation is greatest from west to east. This agrees with earlier climatic studies that concluded that, climatically, the grasslands are more uniform from south to north. The generation of precipitation data for simulation can be represented as a simple first-order Markov process of either a rain or a no-rain day. If a day is rainy, the amount of rain is selected from a frequency distribution for that day of the year.

Wind studies show that wind travel contains a seasonal component but is independent of both temperature and precipitation.

Measurements of overland flow from the microwatersheds have revealed that it occurs more frequently than one might think, but only locally, reinfiltrating before reaching local depressions.

In the primary producer studies it has been learned (1) that shortgrass species respond to significant rainfall events in less than 72 hours, (2) that heavy rainfall rates shatter the standing dead plant parts and are therefore an effective agent of transfer from standing dead to litter, and (3) that root material is concentrated in the top 10 cm of soil, differs from one grazing treatment to another only slightly for the first 8 months of the calendar year, and decreases simultaneously in August under all treatments.

There are a great number of species in the consumer trophic level. In our studies we have developed methods of determining intake, output, numbers, and biomass for all major species. For cattle we have already developed fistulation and fecal-collection methods. We have domesticated a small number of bison and antelope and we perform experiments with them. Of much significance in studies of large herbivores has been the refinement of the water-intake method of estimating daily forage intake. Knowing body size, air temperature, and water intake, we can estimate daily forage intake to within 500 g per animal per day.

When small mammals and birds are studied, determining forage intake and output by nondestructive methods is more difficult. (Even estimating numbers and biomass is more difficult.) Flushing transects have been used for estimating jackrabbits. Ground squirrels, kangaroo rats, deer mice, and grasshopper mice have been trapped in grid systems. Age structure, breeding periods, and preg-

nancy rates have been determined. Birds have been inventoried by count and nest flush techniques.

Dietary studies of small-mammal gut and bird crops have been made by microscopic analysis of the contents. Our studies at the consumer level have been designed to identify the feeding pathways.

The distribution of small mammals across the Pawnee Site is related to soils, intensity of grazing, vegetation patterns, and other factors. Thus far, however, no relationship has been noted between intensity of grazing and the number of grasshopper mice and 13-lined ground squirrels that have been trapped. Because of the lower density of kangaroo rats and deer mice, it is difficult to determine whether there is a relationship between this density and the intensity of grazing; apparently there is none.

There appear to be some relationships between soils and rodents. Ord's kangaroo rats, northern grasshopper mice, and 13-lined ground squirrels tend to avoid poorly drained, undifferentiated bottomland soils. Furthermore, kangaroo rats prefer Renohill-Shingle soils to sandy loams. Prairie deer mice appear to have no soil preference.

Both kangaroo rats and deer mice are much more abundant in specific habitats adjacent to the intensive-study pastures. Prairie deer mice are the most abundant rodents in areas with especially tall grasses or thick shrub cover. Ord's kangaroo rat is probably the primary rodent biomass in sandy areas and in areas with loose soils and low plant coverage. These areas are found along streams on the edge of wheat or barley fields and in low barrow pits near roads.

Hares, perhaps because they are larger and more mobile, show predictable daily and seasonal preferences for assemblages of plants. Although the dispersion patterns are species specific, there are considerable areas of overlap, particularly during the winter. Distribution patterns were investigated and revealed a very strong relationship with vegetational patterns. The black-tailed jackrabbit range occurred where there were stands of fourwing saltbush, or in and near cultivated areas, or along the alluvial plains of the Nunn series soil where western wheatgrass is the predominant grass species. White-tailed jackrabbits, on the other hand, were more common on upland soils where shortgrasses (e. g., blue grama grass) are dominant.

Other examples of relationship between animal distributions and vegetation distributions were found for bird-nesting sites. Lark buntings apparently are more likely to nest near taller vegetation, such as fourwing saltbush and red three-awn. Leafhoppers are more common on the Nunn soil series occupied by western wheatgrass, and grasshoppers are more common on soils occupied by blue grama and buffalo grass. The lark bunting was found in very low numbers on pastures heavily grazed in summer, but large numbers of horned lark and McCown's longspur were usually found on these pastures. Thus, there appears to be a complex, interrelated array of animal, plant, and soil characteristics. Study of the ecosystem at only a few points or considering only averages at many points would obscure many of these interrelationships.

The most obvious herbivorous insects on the Pawnee Site are the orthoptera. The orthoptera are consumed by the 13-lined ground squirrel and the grasshopper mouse, by various small passerine birds, and by carnivorous insects (e. g., robber flies). The orthoptera are an importnat link in the transfer of energy and nutrients from the producer compartment to these omnivorous feeders. Over 30 species of orthopteran insects have been found on the Pawnee Site. The most common species are the grasshoppers. The dominant orthoptera on the Pawnee Site are not known to be agricultural pests. Since investigations began under this program, grasshoppers have invaded nearby cultivated lands, and the infestation was judged severe enough to warrant wide-scale spraying. The pest species was not found on the Pawnee Site, which indicates that certain natural dietary or other controls of pest species are present in native grasslands but not in cultivated lands.

Decomposers play the critical role of transferring organically bound nutrients to their available inorganic states. A very sizable fraction, perhaps more than half, of the ecosystem producer biomass, is not consumed by herbivores but is directly decomposed by fungi and bacteria.

Fungi and bacteria account for most of the decomposition, and attempts were made to determine the biomass of these organisms. Initial bacteria counts were made with a Petroff-Hauser counting chamber; in later studies a modification of the smear technique was used. Fungal biomass values were derived from estimates of mycelium length. These studies indicated that the fungal biomass of soil was about 3 times that of bacterial biomass. For both bacteria and fungi, there was a decrease in biomass with soil depth; it was much more apparent with fungi than with bacteria. A significant seasonal trend also was observed; the biomass of both groups of organisms decreased from July to September.

The determination of microbial numbers or biomass involves the use of procedures that are laborious and time-consuming, and results are often difficult to interpret. To overcome some of these problems, we utilized adenosine triphosphate (ATP) measurements to give us microbial biomass. This method uses the luciferase enzyme system. In the presence of ATP the system emits light, the amount being proportional to the available ATP. The relationship between ATP and bacterial biomass is extremely sensitive and linear over a wide range of values, and it appears that the ATP procedure is satisfactory for estimating biomass of soil bacteria. The major shortcoming of the technique in its present form lies in the uncertainty of its ability to measure accurately the fungal component of soil microflora.

We carried out other research to characterize the rate of decomposition by fungi and bacteria, using filter paper buried at different times during the fall of 1969. These studies indicated, as expected, that plant litter and cellulose disappeared most rapidly during times of warm, wet weather; during periods of very cool weather there was almost no loss of these materials. The techniques will be refined and expanded so that a better quantitative picture of the decomposition rate of below-ground plant material and plant litter can be obtained.

Preliminary work on phyllosphere and litter bacteria involved mostly the selection of suitable nutrient agar for optimum development of these microbial populations. The results indicated that a large proportion of the bacteria associated with living (green) plant tissue required organic growth factors and that a small proportion of the bacteria associated with dead plant tissue required them. These findings suggest that the living plant provides growth factors required by phyllosphere microorganisms and show that direct decomposition of plant material involves a wide range of bacteria.

Soil respiration is an index of the physiological activities of the soil organism and of the turnover rate of the organic matter in the soil. Rates of CO_2 evolution from soil cores were measured in the laboratory. Soil cores were divided into sections taken from depths of 0–3, 3–6, 6–10, 10–20, 20–50, 50–70, and 70–90 cm. During the first day of incubation, CO_2 evolution was about the same for the various upper-core sections. There was a high rate of CO_2 evolution in the sections from the depth of 50–70 cm, indicating that the aeration condition in the extracted cores is considerably different from that of the soil in situ. Future investigations of CO_2 evolution will utilize more frequent sampling in the field, and there will be concurrent measurements of soil temperature and soil moisture at various depths. Also, laboratory investigations will utilize similar techniques where soil moisture and soil temperature are held at constant values.

Nitrogen must be replaced constantly in the ecosystem by various fixation mechanisms, and the fixation rates on the predominantly grass-covered sites are very, very low. The acetylene reduction technique, because of its high sensitivity, is used (Technical Report 7). Cores from an area vegetated with buffalo grass (*Buchloë dactyloides*) and soil cores from the bare-soil area of an intermittent lake were compared while they were saturated with moisture. Cores from buffalo grass areas fixed 5 g per hectare per day, and cores from bare-soil areas fixed 1.2 g per hectare per day.

Addition of a source of soluble energy (sucrose) resulted in a greater increase in nitrogen fixation rates on the (bare-soil) cores than on the sodded-grass cores. This perhaps can be interpreted to mean that the bacteria or algal populations in the intermittent lake situations are more suited for nitrogen fixation. But these areas are more deficient in energy than the grass-covered areas. The results indicate that fixation by free-living bacteria probably is not an important source of nitrogen on the grassland. There may, however, be localized areas with high levels of energy supplying material, coupled with anerobic conditions, that could result in substantial rates of fixation. On the Pawnee Site, these areas are confined to the intermittent lakes.

COMPREHENSIVE NETWORK SITES

Three meetings were held to organize the comprehensive network:

- At the first meeting, held in July 1969, the sites were selected—10 sites in 9 western states—and a general plan of trophic level investigation was worked out for each. The meeting was attended by representatives of each site, subject-area specialists, and some of the scientific coordinators from the central grassland biome office.
- The second meeting was held in November 1969 in conjunction with the annual meeting at the Pawnee Site. During the first 2 days, investigators from the Pawnee Site gave reports on progress achieved in a season of field work. These reports enabled the investigators from the network sites to anticipate problems and to adjust their research designs. In the remaining 1½ days, discussion was devoted to research at the network sites. After a review of important variables in each trophic level, the group divided into workshops on herbage dynamics, vertebrates, invertebrates, and microbiology. In the workshops, plans were made regarding variables to be evaluated, desired precision, and problems requiring further consideration.
- A small group representing the various specialties met in December 1969. They reviewed plans for studying trophic levels and discussed changes in plans that had been made since the November meeting.

The plans and decisions developed during these meetings were summarized in a manual of field procedures for the comprehensive network (Technical Report 35). The variables and measurements required were organized on field data sheets, which were printed and distributed for the use of all field investigators. The forms provide for consistent coding of all data and for organizing them for keypunching.

The 10 network sites selected for investigation in the United States fit into a design for comparing grassland habitats in various parts of North America (Figure 3). Other sites being considered are the Matador Site in Saakatchewan, Canada, and the Campana Site in Chihuahua, Mexico. Investigation of the grasslands biome in three North American nations provides unequalled opportunities for comparative analyses. Such comparisons are essential to understanding the interrelationships of

ecosystem compartments in the function of the total ecosystem.

A certain minimum set of data is required from a site in order for it to contribute to the objectives of the comprehensive network project. Characterization of the driving forces in the abiotic compartment of the ecosystem requires measurement of total and net radiation, precipitation, wind, atmospheric moisture, the temperature gradient above and below the surface of the ground, the gradient of soil moisture, and soil heat flux (see Technical Report 35). Quantitative characterization of primary production requires measurement of above-ground and below-ground plant biomass and litter. Consumer populations, both vertebrate and invertebrate, must be quantified at various times during the season. Decomposer activity must be quantified.

Ten battery-powered micrometeorological packages have been designed and built to record the abiotic variables mentioned here. The package includes a recording unit that will read hourly from 13 sensors and record results on magnetic tape. The tape will be returned monthly to the central grassland biome office, and the results will be summarized, returned to the investigators, and added to the information storage and retrieval system. Appropriate summaries of the data will be distributed to the investigators and scientific coordinators.

A meeting of the investigators and graduate students sampling small mammals on the comprehensive network sites was held in April 1970 at the Jornada Site in New Mexico. Scientists from three universities and one federal agency attended. The investigators participated in a field-sampling exercise to gain experience in solving logistic problems that would be met in the network. This successful effort stimulated similar meetings for other disciplinary groups. For example, a meeting of scientists sampling invertebrates was held at the Pantex Site in Texas.

An experimental evaluation of the effectiveness of the small-mammal sampling program being followed in the grasslands biome was conducted in July in southern Nevada. A group of investigators from the University of California at Los Angeles have regularly censused the rodent populations for several years , using 8-hectare enclosures. Personnel from the subprogram concerned with the desert biome and from the Savannah River Ecology Laboratory participated. IBP sampling methods were applied in the enclosures, and the resulting population estimates were compared with the true values. Certain methods of computing population estimates (e.g., those assuming a geometric frequency distribution of recapture) were excluded as a result of the studies. Other methods gave more realistic values. The procedures followed in the field also permitted determination of the locations from which animals came as they moved toward the traps. Therefore, the effective area of the trapping grid could be evaluated empirically for comparison with the computational methods for evaluation of effective area.

A comparative evaluation of three methods of sampling insect populations was made before field sampling began. Sampling by sweep net grossly underestimated numbers of insects. Sampling by a vacuum net overestimated groups that jump or fly weakly when flushed by the apparatus and underestimated other groups. The quick trap, which encloses an area that is then thoroughly collected by a vacuum device, gave the most accurate estimates.

The length of the growing season varies considerably among sites, and the initiation of field work varies accordingly. Eight sampling periods have been completed for vegetation studies at the Osage Site in Oklahoma. During the same length of time there have been four sampling periods for below-ground biomass, which is determined from soil cores. Two estimates of small mammal populations, one before and one after the breeding season, have been made for five of the sites, and one estimate has been made for two additional sites. Evaluation of the avian populations has been completed at eight of the sites.

MODELING RESULTS

Since initiation of the program in 1968, we have pondered the question of how best to organize the modeling activity, for which manpower was limited. In the autumn of 1969, we organized a group to develop preliminary models. This group included three scientists in ecological modeling and analysis, three persons working primarily in an interactive mode between the analysts and the experimentalists interested in getting their ideas and data into models. Much of our initial activity was devoted to conceptual and methodological reviews of mathematical modeling of ecological systems.*

The systems analysis group has developed several specific subsystem or total-system simulation models:

- An example of a subsystem model is a model of bird population and biomass dynamics, patterned after the Pawnee Site situation (Technical Report 3). This model has two differential equations that, when solved, give the dynamics of bird numbers and biomass. Coefficients in the model are based on data for the lark bunting.
- A more complex analytical model is concerned with the population dynamics of small mammalian herbivores (Technical Report 4).
- A simplified total-ecosystem energy-flow model was developed in 1968 as a preliminary effort for a total

*See references to the following articles in Appendix A (p. 14): "Model Structure for a Grassland Ecosystem," by Bledsoe and Jameson (1969), and "Implementing the Ecosystem Concept in Training in the Natural Resource Sciences," by Van Dyne (1969). See also Technical Report 32.

system. This model contained generalized plants, animals, and microbes with coefficients patterned specifically after warm-season shortgrasses as producers, antelopes as herbivores, and coyotes as predators. In this model an incremental approach was used to update changes in biomass of the animal and plant components in a system. The driving forces utilized in this model were the climatological records from the Pawnee Site.

- An initial complex macromodel, composed of 46 differential equations, was developed early in 1970. This highly nonlinear but deterministic model has four driving variables and 46 principal systems variables.

The systems analysis group also was involved in a variety of specialized mathematical analyses. For example, the dry-weight rank method was examined. We investigated its theory, distributional properties of parameters derived from the model, and limitations of the technique for determining botanical composition of plant communities. Another group of specialized models reviewed includes those for inferring evaporation from meteorological measurements (Technical Report 47).

To provide techniques needed for future stochastic and statistical work, we developed special packages that included distribution generators for the F statistic and the Chi-square statistic. Also, because in stochastic simulations several parameters may need to be varied simultaneously, we developed a generator for multivariate normal distribution. We developed computer programs for solving differential equations, for optimization, and for statistical analyses, then published technical reports to enable participants to make wide use of them (Technical Reports 34 and 46). Analytical personnel have participated in field-based workshops in which special attention was given to sampling problems related to estimating populations of mammals and insects.

INTERDISCIPLINARY RESEARCH

We are making some important changes in the structure of the grassland program. Some unique features are becoming clear.

First, a great deal of time must be spent in program development, organization, and scientific public relations. For example, since 1968, the Grasslands Biome Director has given more than 20 lectures in which he has described, for legislative, scientific, and industrial groups, the concepts and operation of the program.

Second, to maintain the necessary coordination, exchange of information and data, and interaction among the participants, it appears that 0.5 to 1.0 man-month is required for each senior participant simply to attend various types of meetings, seminars, discussion group sessions, and workshops each year.

Third, two major types of senior participants are probably needed in this kind of investigation. Perhaps 80 to 90 percent of the participants should work on individual subprojects requiring about 25 percent of their time. The others should devote their efforts to the overall program and, for about 75 percent of their time, should share work on the following tasks: (1) regional, national, and international development, which includes describing the program to, and evaluating it with, scientific, government, and industrial groups; (2) scientific coordination, which includes program management and administration, organizing and conducting meetings, developing reports and proposals, and planning and evaluation; (3) scientific integration and synthesis, which includes working with participants in different trophic areas of specialization. The program scientists would also pursue individual research in their areas of expertise.

Thus, we need a core of scientists dedicated to the overall program. But our plan also encourages the contributions and cooperation of a much larger number of scientists from universities and federal laboratories. Their cooperation is necessary for a more complete understanding of the entire ecosystem.

APPENDIX A: PUBLICATIONS

Technical Reports*

1 Jameson, D. A., and R. E. Bement. 1969. General description of the Pawnee Site. 32 p.

2 Bartos, D., and J. Hughes. 1969. Preliminary methodology and results for root biomass sampling on the Pawnee Site. 20 p.

3 Swartzman, G. S. 1969. A preliminary bird population dynamics and biomass model. 16 p.

4 Gross, J. E., and C. J. Walters. 1969. Summary report on initial small-herbivorous-mammal modeling efforts. 57 p.

5 Striffler, W. D., and F. M. Smith. 1969. Pawnee Site microwatersheds: selection description and instrumentation. 29 p.

6 Galbraith, A. F. 1969. Soil water study of a shortgrass prairie ecosystem, Pawnee Site. 51 p.

7 Reuss, J. O., and P. W. Copley. 1969. Soil nitrogen investigations, Pawnee Site. 13 p.

8 Jameson, D. A., and L. G. Nell. 1970. Memoranda of agreement and procedures for working on federal lands of the USDA. 53 p.

9 Fisser, H. G. 1969. Preliminary report of methodology and results for analysis of plant pattern subproject research on the Pawnee Site. 65 p.

10 Hyder, D. N., K. L. Knox, and R. E. Bement. 1969. Metabolic components of cattle: water-soluble tracers for determining water turnover and partitioning by cattle. 32 p.

11 Rice, R. W., D. R. Cundy, and P. R. Weyerts. 1969. A comparison of the esophageal fistula with rumen samples for the determination of the botanical and chemical composition of the diet of herbivores. 13 p.

*The number preceding each item is the report number. Copies of these reports may be obtained by writing to the author or to the Grasslands Biome Director (George M. Van Dyne). Supplies are limited.

12 Rice, R. W., and M. Vavra. 1969. Botanical species of plants eaten and intake of steers grazing light, medium, and heavy use shortgrass range. 18 p.

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19 Van Horn, D. H. 1969. Dry weight biomass data for four abundant grasshopper species of the Pawnee Site. 6 p.

20 Lavigne, R. J., and L. E. Rogers. 1970. Effect of insect predators and parasites on grass feeding insects, Pawnee Site. 38 p.

21 Doxtader, K. G. 1969. Microbial biomass measurements at the Pawnee Site: preliminary methodology and results. 16 p.

22 Mayeux, J. V., and E. A. Jones. 1969. Bacterial ecology of grassland soils, Pawnee Site. 13 p.

23 Christensen, M., and A. M. Scarborough. 1969. Soil microfungi investigations, Pawnee Site. 18 p.

24 Wright, R. G. [compiler]. 1970. Scientific personnel participating in the Grassland Biome study, June 1968 through January 1970. 278 p.

25 Robinson, R. D. 1970. IBP Grasslands Biome budget program. 10 p.

26 Ryder, R. A. 1969. Diurnal raptors on the Pawnee Site. 16 p.

27 Marti, C. D. 1969. Some comparisons of feeding ecology of four species of owls in north-central Colorado. 21 p.

28 Giezentanner, J. B., and R. A. Ryder. 1969. Avian distribution and population fluctuations, Pawnee Site. 29 p.

29 Baldwin, P. H., J. D. Butterfield, and P. D. Creighton. 1969. Summer ecology of the lark bunting, Pawnee Site. 37 p.

30 Franklin, W. T. 1969. Mineralogy of representative soils at the Pawnee Site. 10 p.

31 Moir, W. H. 1969. Photosynthesis of shortgrasses under field conditions. 31 p.

32 Swartzman, G. [coordinator]. 1970. Some concepts of modeling. 142 p.

33 Uresk, D., and P. L. Sims. 1969. Preliminary methodology and results for aboveground herbage biomass sampling on the Pawnee Site. 13 p.

34 Swift, D. M. [coordinator]. 1970. Current generalized computer programs used in Grassland Biome analyses. 286 p.

35 French, N. R. 1970. Field data collection procedures for the comprehensive network 1970 season. 35 p.

36 Rickard, W. H., and T. P. O'Farrell. 1970. Comprehensive network site description, arid lands ecology. 5 p.

37 Morris, M. S. 1970. Comprehensive network site description, Bison. 23 p.

38 Collins, D. 1970. Comprehensive network site description, Bridger. 10 p.

39 Lewis, J. K. 1970. Comprehensive network site description, Cottonwood. 26 p.

40 Whitman, W. C. 1970. Comprehensive network site description, Dickinson. 15 p.

41 Tomanek, G. W. 1970. Comprehensive network site description, Hays. 6 p.

42 Heady, H. F. 1970. Comprehensive network site description, Hopland. 11 p.

43 Herbel, C. H., and R. D. Pieper. 1970. Comprehensive network site description, Jornada. 21 p.

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45 Huddleston, E. W. 1970. Comprehensive network site description, Pantex. 12 p.

46 Bledsoe, L. J. 1970. ODE: numerical analysis for ordinary differential equations. 42 p.

47 Nunn, J., L. J. Bledsoe, and R. D. Burman. 1970. Models for inferring evaporation from meteorological measurements. 20 p.

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DECIDUOUS FOREST BIOME

Deciduous forests are the dominant vegetation in nearly 30 states in the eastern and midwestern United States, covering about 350 million acres. This acreage is about 52 percent of the total acreage in the two regions and about 50 percent of the total forest acreage in the United States.

The deciduous forests of the United States are the basis of important lumber and wood-product industries, and they are a valuable recreational and conservation resource. The forested cover affects the yield and quality of fresh water from the watershed.

The fertile floodplains of drainage basins are among the most productive agricultural lands in the world, and most of the nation's inland urban complexes have developed adjacent to these centers of food production. The combination of land and water resources (food, fiber, transportation, and water) supports intensive industrial development and population concentrations. About 75 percent of the U.S. population lives in the temperate deciduous forest biome; more than 70 percent of these people live in urban areas.

The deciduous forest biome program is one of six biome programs designed to analyze the ecological and related physical processes that serve to regulate forested, agricultural, and aquatic ecosystems. Through modern integrative and synthesis techniques (e. g., systems analysis and computer simulation modeling), predictive models of key processes in ecosystems as well as models of entire ecosystems are being developed. Particular emphasis is being placed on the development of integrated models of interacting land and water systems since these systems are being subjected to the greatest stresses. By combining studies of basic ecosystem processes with studies of landwater systems now undergoing modification by man, it may be possible to derive a scientific basis for resource management and for long-term utilization of land and water.

RESEARCH PLANS

Research in the deciduous forest biome is planned to develop an understanding of forest ecosystems in several geographic areas and at several levels of complexity so that realistic predictions can be made in terms of geographical and biological patterns. To achieve this generality, the program is organized around a number of major sites with representative local and regional characteristics. Studies at these major sites are being augmented

by a comprehensive network of individual studies to provide the necessary geographic coverage.

Much of the program is oriented toward analysis of some of the basic production processes that regulate forest and aquatic ecosystems: biological productivity, nutrient cycling, food chain mechanisms, energy flow, hydrologic cycles, and exchanges between systems. In related studies, ecosystem components will be monitored and changes (e. g., in standing crops of vegetation or in animal biomass) will be monitored. The resulting data will be combined with data from projects in which emphasis was placed on experimental manipulations of ecosystem units. One phase of the experimental treatment will include addition of nutrients (or deletion, as in forest cutting or water treatment techniques) to provide more exact control of variables as a means of determining the extent to which manipulation of one ecosystem component influences the structure and function of other components.

Although the research will be concerned primarily with the chemical relationships between forest and aquatic ecosystems, the importance of agriculture in this biome will not be overlooked. Much of the agricultural and urban-suburban areas utilize what was originally forest land. Because of future needs for food and fiber, it seems desirable to study both the quality and the quantity of total production in some forest and agricultural ecosystems. However, these investigations will be postponed until the initial research has delineated suitable methods and appropriate aspects for emphasis. Social criteria, ecological indices, and system modeling will be combined to design studies and experiments that will yield widely applicable information.

Systems analysis, which provides the mechanism for investigators from many different disciplines to work together, will operate at all levels of research planning, data analysis, and model synthesis.

SITES

Five major sites have been selected for process studies in an ecosystem context (Figure 4). They provide a combination of environmental situations typical of major parts of the biome. By grouping process studies at each of these sites, it will be possible to assemble and organize ecosystem analyses at different levels of complexity and for different geographical coverage.

1. Oak Ridge (Oak Ridge National Laboratory); located in the basin of the upper Tennessee River. This site has a major facility for studying interactions between land and water. Water and related terrestrial nutrient cycling is being investigated in dolomitic limestone terrain. The streams draining the well-instrumented Walker

FIGURE 4 Sites for research on the deciduous forest biome.

Branch watershed empty into Melton Hill Lake, an embayment of the Tennessee River system. The ecology group at the Laboratory is dedicated to integrated ecosystem research and is one of the largest groups of its kind in the country.

2. Lake Wingra (University of Wisconsin); located at Madison, Wisconsin. This site offers great potential for studying the impact of urban, suburban, and recreational use on a body of water. Research will include the ecology of lake basins, hydrology, and related physical systems. The University of Wisconsin group has done distinguished work in limnology and related studies.

3. Lake George (Rensselaer Polytechnic Institute); located on the eastern edge of the Adirondack province. Lake George is an oligotrophic lake that is receiving increased amounts of pollution from the resort development in the southern subbasin. Groups at RPI and several branches of the State University of New York have organized an enthusiastic team of investigators.

4. Coweeta (University of Georgia and U.S. Forest Service); located in the basin of the upper Tennessee River. The stream system is on base-poor crystalline bedrock, and studies of interaction between land and water are being conducted here. Data from these studies will be compared with those from studies in the lime-rich basin of the Oak Ridge site and with those from the Hubbard Brook (New Hampshire) study. The University of Georgia is the center of a well-known ecology group.

5. Triangle (U.S. Forest Service, Duke University, University of North Carolina, and North Carolina State University); located on the edge of the Piedmont Plateau near the Costal Plain. This site is characterized by secondary southern pine forests normally replaced by deciduous

forest. Work here emphasizes photosynthesis, forest productivity, and related meteorology. The Triangle group has a large number of ecologists, and two major phytotrons are available, one at Duke University and the other at North Carolina State University.

Selected process studies are being conducted at other sites by other groups. The additional studies are analogous to the "comprehensive" programs of the other biomes, being intended to augment the data base. Initially, only a few are being funded from the grant for the deciduous forest biome. Inclusion of more sites will depend on the development and progress of research at the five major sites.

ORGANIZATION

S. I. Auerbach is the Deciduous Forest Biome Director. He is assisted by R. L. Burgess, who is Deputy Director, by an administrative assistant, and by research coordinators. The organizational structure below the level of the Deputy Director and the administrative assistant is shown in the following list:

A. International coordination (J. S. Olson)
B. Interbiome coordination (F. Glenn Goff)
C. Resource region modeling and site modeling
   1. Coordinator (R. V. O'Neill)
   2. Modeling committee
D. Major sites
   1. Oak Ridge (D. E. Reichle, coordinator)
   2. Lake Wingra (O. Loucks, coordinator)
   3. Lake George (N. Clesceri, coordinator)
   4. Coweeta (C. D. Monk, coordinator)
   5. Triangle (B. Strain, coordinator)
E. Process studies
   1. Primary productivity
   2. Secondary productivity
   3. Decomposition processes and soils
   4. Land-water interactions
   5. Streams
   6. Lakes
F. Comprehensive and related studies

Technical modeling services, data processing, editorial services, chemical services, and remote sensing services are provided by the central biome office.

The first level of synthesis is with the research teams working on ecosystem processes. These teams synthesize data into relevant forms, developing submodels of the processes and working toward general process models. A second level of integration takes place at each site. Here the different process studies are brought together so that the data for modeling and simulation are appropriately related (e. g., primary productivity to secondary production to decomposition). The integration of these subsystem processes is the responsibility of the site coordinators. Finally, the overall integration of results and development of biome models is the responsibility of the Biome Director.

RESEARCH METHODS AND PROGRESS

Initial funding for the biome was made available in 1969. It provided for initiation of modeling research and lead-time investigations on certain process studies. Modeling research was begun at the Oak Ridge, Lake Wingra, Lake George, and Triangle sites and in the Biome Director's office. Initial studies of water chemistry and aquatic primary productivity were started at Lake Wingra and Lake George; work on primary production in terrestrial ecosystems was started at the Triangle site.

The modeling program at the Lake Wingra site has focused on the movement of energy and carbon in the aquatic system and the coupling of biomass simulation capability with nutrient and water environment simulations. Energy-transfer, water-transfer, and nitrogen-transfer flow charts have been developed in matrix form. The energy output at each juncture of the matrix involves a process: reflection, absorption, photosynthesis, reradiation, vaporization, condensation, respiration, fire, transport (migration, litter fall), ingestion (grazing, predation), assimilation, excretion, decomposition, mortality, and replication. These studies have contributed to the development of a more detailed research design for the studies land and water interaction.

Modeling of the Lake George aquatic ecosystem uses empirical relationships among diatoms, key nutrients, and other chemical and physical factors. The construction and evaluation of certain models have been aided by regression analyses and by graphical procedures where the data were sparse or incomplete. These analyses indicated (1) that both phosphorus and nitrogen are limiting at certain times, and other nutrients and growth factors may be limiting; (2) that nutrient levels vary seasonally (apparently in response to seasonal influxes of vacationers); and (3) that nutrient and corresponding productivity gradients are closely related to summer population density.

Simple compartment models, based partly on the observed relationships and partly on published material, have been designed and programmed. From these initial models, it is evident that the relationships between the primary producer compartment and the available nutrient compartment are crucial. Because several nutrients may

be at threshold levels at a given time, relatively detailed modeling is required. Programming is being initiated to develop models that can be easily modified as more adequate empirical models are developed for the compartment components.

At the Triangle site, a group at Duke University has been modeling a deciduous forest stand energy budget. The energy exchange between a forest stand and the environment surrounding it has been simulated by finding a simultaneous solution to a set of equations (based on continuum thermodynamics and fluid mechanics) that describe the energy exchange process. While this model does not directly estimate the photosynthesis or respiration of forest stands, it does provide a quantitative description of the stand environment that can be used to make indirect estimates of these quantities.

A technical modeling group has been formed at the Oak Ridge site. This group is charged with providing technical support to the modeling effort throughout the biome and with developing a general forest ecosystem model. It has encouraged publication of a data retrieval program specifically designed for ecological data. Other tasks in progress include an annotated bibliography of modeling literature, a review of relevant computer techniques and programs, and a study on methods of solving differential equations in ecosystem models.

APPENDIX A: PUBLICATIONS

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Hull, Norma, J. Beauchamp, and D. Reichle. 1970. Pitfall I: a general purpose data processing program for environmental data. ORNL-IBP-70-2. (Oak Ridge National Laboratory, Tenn.)

Reichle, D. [ed.] 1970. Analysis of temperate forest ecosystems. (Based on IBP/PT meeting held in Gatlinburg, Tenn.) Springer-Verlag, Heidelberg and New York.

Taylor, F. 1969. Phenological records of vascular plants at Oak Ridge, Tennessee. ORNL-IBP-69-1. (Oak Ridge National Laboratory, Tenn.)

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CONIFEROUS FOREST BIOME

Because of diversity of environments, species, soils, products, and land uses, single approaches to managing the western coniferous forest are impossible. The use and misuse of the forest by modern colonizers moving westward led to complicated efforts to understand the forest. The time-honored use of the forest as a source of agricultural land is being replaced by use for suburban and recreational development. As a result, large numbers of people are impinging on sensitive ecosystems.

RESEARCH PLANS

Research in the coniferous forest biome will include process studies, computer modeling, and validation studies, in that sequence. As discrepancies are encountered between the predictions of the simulation model and field observations and validation studies, explanations will be sought and new process studies will be suggested. The new studies will refine and extend the range of applicability of the functions that will be incorporated in local, and eventually biome-wide, ecosystem models.

Since our purpose is to increase understanding of whole ecosystems within the coniferous forest biome, we study processes and develop models that are relevant to entire systems. Accordingly, each project, however narrow or detailed, will develop a submodel that relates to an essential component of the system. At all major sites within the biome, simulation models are being developed that describe the behavior of subsystems within the local ecosystem. Later, simulation models for entire local ecosystems will be developed by combining models of local subsystems.

During the initial phase of this program extensive use is made of past studies. Existing models of biomass, mineral cycling, primary production, and population dynamics that exist for a number of ecosystems at selected intensive study sites are being further analyzed, tested, and applied to new communities. New field studies will be initiated as they are suggested by the initial modeling program. In these new studies, careful attention will be given to relations between the aquatic and terrestrial components.

Later phases will emphasize:

- Expansion of current studies to the other important ecosystems
- Continued development of the process and validation studies in ways suggested by the modeling programs and simulation studies
- Coordination of existing process studies and the modeling programs throughout the biome
- Development of new biome-wide studies that will help in understanding basic processes and behavior within the biome

We are not attempting to construct biome-wide simulation models during early stages of the work. Instead, investigators and modelers at each site will develop models of local subsystems and combine these with computer models of the local ecosystems. Frequent seminars, conferences, and visits enable modelers at the intensive and coordinating sites to maintain close contact with one another and with modelers working on other biomes.

In the final stages, emphasis will be placed on integration of research results. Biome-wide models of processes in subsystems, such as models describing movement of water and nutrients through soils or the growth and development of certain organisms that are widely distributed over the biome, will be attempted. In addition, models of entire local ecosystems will be compared and the feasibility of constructing biome-wide models for whole ecosystems will be studied.

SITES

The coniferous forest biome encompasses a wide range of forest ecosystems varying markedly in environment, composition, structure, and productivity. These ecosystems are managed differently because their resources are valued differently. A general model of coniferous forest ecosystems must reflect reality by encompassing this variability in intrinsic character and manipulative practice. For this reason, research will be carried out at several study sites. Further, a requirement for data relating one process to another quantitatively and for linking the terrestrial and aquatic components of the ecosystems makes it essential that representative sites have a history of research development and sufficient scientific man-

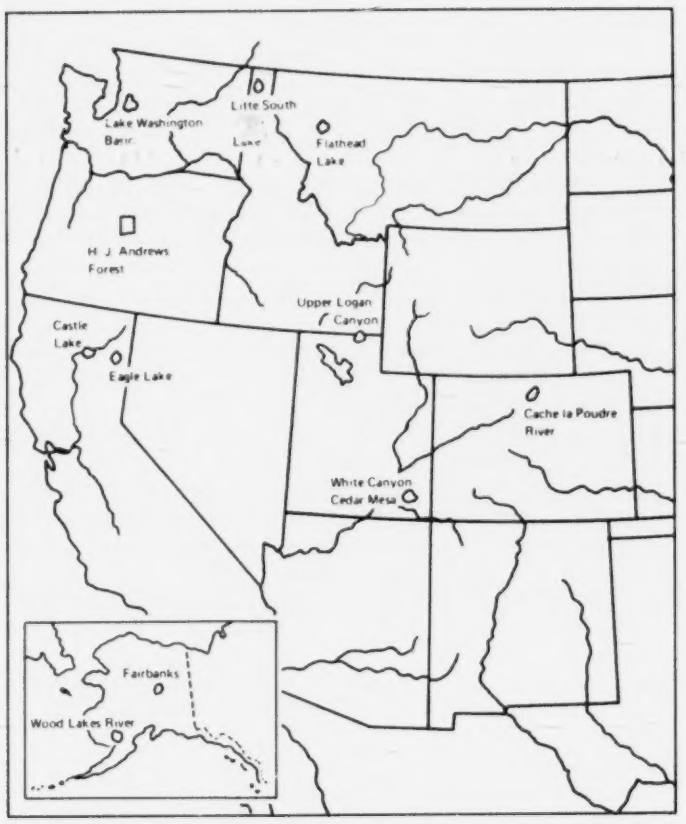

FIGURE 5 Sites for research on the coniferous forest biome.

power to conduct the research. Fortunately, several such sites are available (Figure 5).

The initial biome research is carried out on two intensive sites: the H. J. Andrews Experimental Forest and the drainage basin of Lake Washington. For both areas considerable inventory and process data are already available and will form the basis for initial modeling activity, along with data from Castle Lake in California and Wood River Lakes in Alaska. As the research activity expands, additional sites for coordinated validation studies will be selected.

The H. J. Andrews Experimental Forest is a 15,000-acre drainage basin in the Oregon part of the Cascade Range and is administered by the Pacific Northwest Forest and Range Experiment Station, U.S. Forest Service. The environment and vegetation are typical of much of western Oregon and Washington. Old-growth (450 years old) Douglas-fir and western hemlock forests are dominant in areas below 3,000 ft. Above 3,000 ft true fir and hemlock forests are dominant; however, extensive areas of Douglas-fir, 60 to 125 years old, and 1,500 acres of cutovers, up to 16 years old, are also present. Mature topography, elevations of 1,500 to 5,300 ft, volcanic bedrock, reddish-brown lateritic and podzolic soils, and a maritime climate with annual rainfall of 94 inches characterize the environment. A market evaluation for the resources would rank wood production, water protection, and recreational use (camping, fishing, and hunting) among the highest management priorities.

The drainage basin of Lake Washington consists of two distinct subdrainages, the Sammamish and Cedar River valleys in central Washington. These two drainage systems differ greatly in both physiography and the patterns of land use. The Lake Sammamish system, which includes Lake Sammamish, the Sammamish Slough, and a variety of tributary systems, including Issaquah Creek, has relatively low elevation and is subject to heavy pressures of urbanization and agricultural practices. Although a series of restrictions have been placed on direct pollution of these water systems, the area still receives a very high input of nutrients through secondary sources.

The area drained by the Cedar River system has an elevation higher than that drained by the Lake Sammamish system, and it consists primarily of forest ecosystems. The Cedar River system includes several small lakes at an elevation of more than 3,500 ft, a large reservoir system at an elevation of 1,555 ft, and Cedar River. The parts of the system that have an elevation of more than 600 feet belong to the watershed from which the city of Seattle receives its water supply. Consequently, this area is carefully protected, and access is rigidly controlled. The forest ecosystems have been systematically harvested and reforested during the past 60 years, and the process has provided a wide range of forest ages and types. Climate is maritime. Precipitation ranges between 50 and 100 inches, the amount depending on elevation. Soils are diverse in nature and origin. The soils at lower elevations range from alluvial to glacial outwash. The soils at higher elevations consist of residuum from the weathering of Andesite with a volcanic ash cover.

Nine coordination sites have been proposed. Their names and the states in which they are located are as follows: Cache la Poudre River, Colorado; Castle Lake, California; Fairbanks area, Alaska; Flathead Lake, Montana; Eagle Lake, California; Little South Priest Lake, Idaho; upper Logan Canyon, Utah; White Canyon-Cedar Mesa, Utah; Wood River Lakes, Alaska.

ORGANIZATION

Overall policy is developed by the Executive Committee. Stanley P. Gessel is Biome Director. He is assisted by two Deputy Directors and an administrative assistant. The rest of the organizational structure is shown in the following list:

A. Planning and Program Design Committee (directors; chairmen of research and site area committees)
B. Research committees
   1. Terrestrial producers
      a. Biomass and structure
      b. Processes
   2. Terrestrial consumers

3. Terrestrial decomposers
4. Aquatic
5. Aquatic-terrestrial interface
   a. Nutrient cycling
   b. Hydrology
   c. Meteorology
6. Genetics
7. Modeling

C. Technical committees
1. Remote sensing
2. Communication
3. Chemical analysis
4. International
5. Data bank

D. Site area committees
1. Intensive sites
   a. H. J. Andrews site
   b. Drainage basin of Lake Washington
2. Coordination sites

RESEARCH METHODS AND PROGRESS

Since the coniferous biome subprogram was not funded until September 1970, research results have been limited.

Results of studies on mineral cycling and biomass at Cedar River are well documented, and various publications describe the characteristics of the principal watersheds at H. J. Andrews. A summary of this work shows the effect of certain forest practices on the quantity and quality of water in experimental streams. A unique development has been the perfection of a proportional automatic water sampling device for use in studies of stream water quality and mineral cycling. Considerable information on elemental composition of surface drainage waters is now available for mineral cycling models. The principal types of vegetation have been described and the soils have been mapped. Scientists planning and conducting biome research on the H. J. Andrews Experimental Forest have been using other financial resources. The results of this research will be used in an initial modeling effort.

Large quantities of data on the nutrient status and productivity of Lake Washington are available from past and current work. Considerable information has been developed on the soils, on water and elemental movement, on standing biomass, and on the effect of some manipulations (e. g., addition of elements and forest removal).

Considerable information has been developed for Castle Lake, and it will be the basis for modeling research in the initial biome work, similarly information is available for sites in California and Alaska.

APPENDIX A: PUBLICATIONS

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DESERT BIOME

The desert biome subprogram is concerned with the shrub-dominated ecosystems in the arid and semiarid lands of the western and southwestern United States, where the annual precipitation is less than 300 mm. This program also has marginal relevance to those areas where the annual precipitation is between 300 and 400 mm. They are exceptionally vulnerable to ill-considered use and, in many places, are subject to rapid change. Increased knowledge concerning the ecosystems in this region would have scientific and practical value.

The arid lands of North America are divided into four main regions, in each of which desert biome studies are in progress. The regions are:

- The Great Basin: cold deserts with continuous snow cover in winter, mainly at an altitude above 1,000 m, in the region between the Rocky Mountains and the ranges along the Pacific coast. The precipitation is 200 to 300 mm.
- The Mohave Desert: in the interior of California and southern Nevada, mainly at an altitude of 500 m or more, with cool winters and very hot summers. The precipitation is usually under 200 mm and is highly irregular.
- The Sonoran Desert: in southern Arizona and northwestern Mexico. The precipitation is 200 to 300 mm; seasonal peaks occur in summer and winter. Winters are warm, summers hot.
- The Chihuahuan Desert: in New Mexico, western Texas, and northeastern Mexico. The precipitation is 200 to 300 mm; a seasonal peak occurs in summer.

To understand the biological basis of productivity in these ecosystems, we must first understand their dynamics and functioning. If this understanding is wide and deep enough, it can aid greatly in predicting effects of pressures, stresses, and manipulations on the ecosystems, and hence can direct their wise use and management.

RESEARCH PLANS

Research activities are concentrated on building simulation models of the desert ecosystems. Process studies needed to provide information for model building, and validation studies to check the performance of the models, are included.

VALIDATION STUDIES

In all the validation studies a complete inventory of the biota will be taken initially, abiotic conditions will be monitored continuously, and changes in the biota will be recorded at regular intervals to provide data for comparison with the output of the computer model.

Ten sites, two of which are for aquatic studies only, have been selected for validation studies (Figure 6). The sites are well distributed through the desert areas, have sufficient experienced manpower available, are accessible, and are free from interference. Of these 10 sites, 6 will be in operation by 1971. They are:

- Curlew Valley, Idaho and Utah; altitude 1,300–1,600 m. The site lies near the center of the Great Basin.

FIGURE 6 Sites for validation studies of the desert biome.

Two areas have been selected, both of which have sagebrush as the native dominant plant. One area is near the upper rainfall limit and the other is near the lower rainfall limit of the valley (200 and 350 mm). Each area is matched with a similar one that is subjected to reseeding. Three aquatic studies are also to be conducted, one in a small reservoir, one in a creek, and one in a saline spring.

- Saratoga Springs, California; altitude 60 m; precipitation 100 mm. This saline aquatic site at the south end of Death Valley represents aquatic ecosystems of the Mohave Desert. It will permit comparisons with the similar environment of Locomotive Springs (Curlew Valley) in the Great Basin.
- Rock Valley, Nevada; altitude 1,000 m; precipitation 100 mm. The site represents the Mohave Desert. It lies 80 miles northwest of Las Vegas and drains into the southern end of Death Valley. It is a broad bajada dominated by *Larrea divaricata* and other shrubs.
- Sycamore Creek, Arizona; altitude 600–1,000 m. This creek, which is a tributary of the Salt River, is an example of a watercourse in the southern deserts. Precipitation in the lower part of the watercourse is 200–300 mm.
- Tucson, Arizona; altitude 800–1,000 m. The Sonoran Desert is represented by six areas near Tucson, where rainfall averages about 250 mm. Four areas lie in the Santa Rita Experimental Range, where vegetation is dominated by *Cercidium* spp., *Prosopis juliflora*, and *Opuntia* spp. One of these will be subject to shrub clearing by chemical treatment, one will be subject to burning, and the other two will be differentiated by permitting or preventing cattle grazing. Two additional areas will be located in the Avra Valley bajada, west of Tucson. In this bajada, *Larrea divaricata* and *Cercidium microphyllum* share dominance with various cacti. *Larrea* shrubs will be cleared from one area and the other will be left undisturbed.
- Jornada, New Mexico; altitude 1,400 m; precipitation 210 mm. An area northeast of Las Cruces represents the Chihuahuan Desert. A well-defined catchment in this area drains into a seasonal playa. Two adjacent areas are included in the site. Shrubs will be cleared from one area and the other will be left undisturbed.

Initiation of validation studies at the other sites has been postponed until funding difficulties are resolved. The other sites are:

- Hanford Reservation, Washington; altitude 200 m; precipitation 180 mm. The site lies near the northern limit of the U.S. cold desert. It includes sagebrush vegetation that was cleared 25 years ago and is reverting to its original state. It also includes a creek that will be the site of the aquatic studies.
- Alkali Flat, Wyoming; altitude 200 m; precipitation 250 mm. The site lies in the Red Desert of Wyoming. Two areas have been selected; one is dominated by *Artemisia tridentata* and the other by *Atriplex gardneri.*
- Pine Valley, Utah; altitude 1,600 m; precipitation 150 mm. The site is near the southern edge of the Great Basin. Four areas of vegetation, dominated by *Atriplex confertifolia,* will be subject to different kinds of grazing management.
- Deep Canyon, California; altitude 300–1,000 m; precipitation 100 mm. The site lies in the Colorado Desert near the town of Palm Desert. It consists of a steep valley in which there is a creek that includes some semipermanent pools. The vegetation is dominated by *Larrea divaricata* and *Opuntia* spp.

PROCESS STUDIES

It is not possible to determine *a priori* which ecosystem constituents and which processes are likely to be most important in the dynamic functioning of the ecosystems. Their relative importance will become apparent only as the modeling activities proceed and after the initial inventories for the validation study areas have been completed. The interactive nature of the program implies that the list of processes and subsystems to be studied must be constantly open to revision. However, a tentative indication of the processes that are expected to require study are given below. In some cases it will be

possible to make use of data already in existence; for most of these processes, however, *ad hoc* studies will be required.

Terrestrial Ecosystems

Micrometeorology For each of the major community types occurring in the sites of the validation studies, functions or submodels will be developed in which the values of meteorological variables in the immediate vicinity of the biota will be related to those measured in the permanent recording stations.

Special attention will be paid to distinguishable positions within the plant community where micrometeorological conditions are sufficiently different to constitute a specialized niche.

Soil Subsystems In order that the conditions surrounding plant roots and soil organisms may be adequately represented in the computer model, it will be necessary to develop a submodel by which the changes in physical and chemical variables at particular points in the soil mass can be calculated as functions of state variables in the ecosystem at large. A submodel is particularly desirable where meteorological inputs must be calculated.

Concurrently, detailed field observations will be made on the changes undergone by the physical and chemical parameters in certain soils. The observations will serve as a check on the submodel and will identify improvements that should be made.

Additional process studies will cover the effects of biota (plant roots, arthropods, burrowing vertebrates, microorganisms, lichens, and algae) on the physical and chemical properties of the soil.

Plants For each of the plant species important at one or more validation studies, a series of processes will be studied in order to design a model in which the abiotic environment can be represented. The possibilities of ecotypic or geographical variation in behavior within a species will be borne in mind throughout.

The processes studied will include water uptake and transpiration, stomatal behavior, net photosynthesis, growth and loss of aerial vegetative organs, root growth, nutrient uptake, flowering and fruiting, and seed germination and seedling establishment. The rate of each process will be expressed as a function of the variables within the ecosystems that influence it.

Animals For each animal species or group of species important in one or more of the validation studies, the following processes will be studied insofar as appropriate: Distributional pattern (including territorial behavior, quantity and composition of food consumed, change in biomass (including fat content), excretion, mortality (other than predation), and reproduction. The possibility of geographic differentiation within the species will be borne in mind.

For each age and sex class, each process will be studied separately as a function of the various factors influencing it.

Soil Organisms For soil arthropods and perhaps nematodes, the questions to be answered by the process studies do not differ from those for other animal groups. For microorganisms, the approach may need to be modfied. It may not be practicable to perform regular censuses of the populations, species by species. Instead it may be necessary to treat the soil microflora collectively and consider its various types of activity (breakdown of organic matter, nitrification and denitrification, nitrogen fixation, etc.) as functions of the controlling factors: temperature, soil moisture, soil organic matter, aeration, and composition of soil solution. The marked effects that some microorganisms have on soil structure, particularly on the crusting properties of the soil surface, will also be studied.

Aquatic Ecosystems

Abiotic Subsystems As with meteorological and soil subsystems in terrestrial ecosystems, so studies on the physical and chemical characteristics of aqueous environments as functions of input and output will be needed. Submodels will be required, for instance, of stream flow patterns, of temperature distribution in flowing and standing water, of changes in chemical composition during drying and refilling cycles, and the like. All these submodels will provide a means for relating the conditions within the ecosystem, which are immediately relevant to the functioning of the organisms in it, to the imposed external conditions.

Phytoplankton and Microorganisms As with soil microorganisms, it may be necessary to treat the mixed population as a single collective entity, or in a few general categories only, for the purpose of process studies. The functions to be studied will include photosynthesis, respiration, nutrient uptake and biomass changes.

Benthic and Littoral Plants The functions to be studied for these plants in the aquatic environment are in general the same as for terrestrial plants (see above), except that water relations are irrelevant.

Animals The functions to be studied for aquatic animals are the same as for terrestrial animals. Except for the fish, however, there is little knowledge of the relative importance of different animal groups in aquatic eco-

systems, and decisions on priorities for process studies will have to await the early results of modeling and validation studies.

MANAGEMENT

D. W. Goodall is Director of the desert biome subprogram and F. H. Wagner is Deputy Director. K. W. Bridges is Chief Modeler. Validation studies are grouped by sites, and each group is in charge of a coordinator. Similarly, process studies are grouped by subject-matter areas, and each group is in charge of a coordinator. The Director, the Deputy Director, the Chief Modeler, and the coordinators make up the Executive Committee. The coordinators are identified in the Appendix (p. 31).

RESEARCH METHODS AND PROGRESS

Funding of this program began, on a restricted scale, in January 1970. A description of progress during the first six months of operation follows.

MODELING AND DATA PROCESSING

Collaborators at each of the main study sites have prepared word models of the systems with which they are concerned. These models describe the major structural and functional relationships between the components of the ecosystem, so far as they are known, and they will serve as a basis for developing mathematical models for computer simulation.

As a first step in the more formal modeling part of the program, K. M. Bridges has developed a computer model for the Saratoga Springs ecosystem (see the list of validation studies, above). He used data collected by J. E. Deacon.

The major species occurring in the pond are represented as compartments in Dr. Bridge's model. Biological interactions between the species are considered as aspects of energy flow between compartments. The model has been structured around an event chain that allows the scheduling of discrete events. Approximate relationships for most of the energy-flow rates have been determined; hence it will be possible to check the model against the validation data.

Facilities have been developed for the computer storage of all data collected in the biome operations, for processing the data, and for summarizing and retrieving them. These facilities will enable collaborators to communicate rapidly with one another concerning research results and will give the modeling group rapid access to the data they need.

VALIDATION STUDIES

Methodology

Certain methodological requirements of the validation studies are being considered in *ad hoc* investigations.

The direct measurement of the water balance of desert ecosystems often poses difficulties. Accordingly, J. L. Thames is exploring an indirect approach based on sampling of precipitation and soil moisture, D. F. Balph and C. D. Jorgensen are studying nondestructive methods of estimating populations of desert vertebrates, and G. L. Bender is responsible for similar studies of invertebrates.

Specific Areas

Validation studies initiated during 1970 included the terrestrial studies at Tucson, a study of the temporary playa at Jornada, and the aquatic studies in Curlew Valley.

At Tucson, the four areas on the Santa Rita Experimental Range have been fenced and treated; an elaborate meteorological station with remote continuous recording has been established; and initial inventories of plants, vertebrates, and most invertebrate groups have been conducted. Some work on the biological inventories has also been performed on the Avra Valley bajada. (Project leader: J. L. Thames.)

At Jornada, some preliminary records of vegetation have been made on the whole catchment, but most observations during 1970 have been limited to the playa. The playa filled with water during heavy rains in July 1970, but prior to this time a full inventory of plants and animals had been conducted. The rapid development of microorganisms, insects, and amphibia after the flooding was followed in detail. (Project leader: W. G. Whitford.)

In Curlew Valley, aquatic studies have begun in Locomotive Springs, at the south end of the valley, and at four stations (spread over 30 km) in Deep Creek. At each station, abiotic conditions are being monitored, and a full inventory of algae, macrophytes, invertebrates, and fish has been conducted. (Project leaders: G. W. Minshall and J. M. Neuhold.)

PROCESS STUDIES

An important task during the first year has been that of assembling data (published and unpublished) that may be relevant and deriving from early work in the validation and modeling studies better guidance to the relative im-

portance of different processes in the ecosystem. However, a few process studies were initiated in the field during the first year:

- *Opuntia* species in the Sonoran Desert—photosynthesis, productivity, and water relations (D. T. Patten, Arizona State University).
- *Sitanion hystrix*, an important perennial grass in the Great Basin—photosynthesis, root and shoot growth, and water relations (M. Hironaka and E. W. Tisdale, University of Idaho).
- *Atriplex confertifolia* and *Eurotia lanata*, two Chenopodiaceous shrubs important in many parts of the Great Basin—photosynthesis, root and shoot growth, and water and nutrient relations (M. M. Caldwell and N. E. West, Utah State University).
- Rodents and lagomorphs in the Sonoran Desert—diets, food preferences, and reproductive cycles (R. P. Balda, G. C. Bateman, and T. A. Vaughan, Northern Arizona University).
- Rodents of the Great Basin—food utilization and assimilation (D. R. Johnson, University of Idaho).
- The role of algae in formation of soil crust (R. E. Cameron, California Institute of Technology).

APPENDIX: PARTICIPANTS

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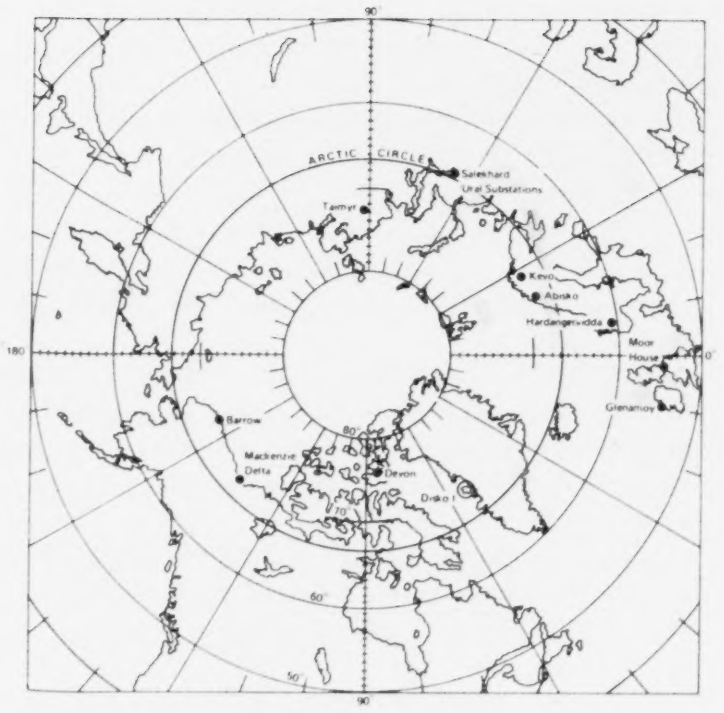

FIGURE 7 Circumpolar areas designated as sites for intensive tundra research. The areas and the nations having jurisdiction over them are as follows: Devon Island (Cape Sparbo) and Mackenzie Delta, Canada; Kevo, Finland; Moor House, Great Britain; Disko Island, Greenland (Denmark); Glenamoy, Ireland; Hardangervidda, Norway; Abisco, Sweden; Barrow, Alaska, United States; Niwot Ridge, Colorado (not shown on map), United States; Taimyr Peninsula (Pyasina River) and Salekhard (Polar Urals), Union of Soviet Socialist Republics.

TUNDRA BIOME

The main purpose of the U.S. tundra biome program is to analyze the structure and function of the wet arctic tundra. The research is designed to develop a predictive understanding of the wet tundra ecosystem and will emphasize the application of environmental knowledge to the problems of degradation, maintenance, and restoration of these ecosystems.

Numerous international sites, most of which are in the circumpolar region, have been selected (Figure 7). An alpine site in the Colorado Rockies is included in the U.S. program.

The arctic and subarctic ecosystems respond dramatically to seemingly minor perturbations. This response is, in part, the result of increased energy flow into the upper substrate as the insulating covers of vegetation and peat are grazed, physically disrupted, or removed. The physical consequences are acceleration of thaw and rapid erosion of the underlying ice-rich permafrost. These consequences are easily observed and measured. However, the biological responses to disturbances and to steps taken to reduce them are not easily observed, and their consequences are not immediately known. Thus, it is essential to investigate these responses. Initial changes must be studied, and cumulative effects must be anticipated and measured.

Many biological responses to disturbances in the arctic and subartic ecosystems are related to warmer surface and substrate conditions and increased availability of nutrients. Increases in primary production during the short growing season result from rapid initial release of nutrients in the physically disturbed organic layers and from release of previously inaccessible nutrients in the lower root zones and thawing permafrost. Initial modifications in the nutrient and energy flows can be followed by comparing, at both disturbed and undisturbed sites, such parameters as available nutrients, metabolic activities, population dynamics (microorganisms and larger

consumers), and thermal regimes in the vegetative and soil covers.

RESEARCH PLANS

During the summer of 1970, an integrated bioenvironmental program was begun in northern and central Alaska. Barrow, the intensive site, and several comparative sites are situated along a bioclimatic gradient ranging from the Arctic Ocean to the taiga of interior Alaska. This research is designed to evaluate temporal and spatial variations in rates and patterns of nutrient cycling and energy flow in natural and perturbed arctic and subarctic environments. Also evaluated are the effects of man-made disturbances and simulated natural stresses on nutrient cycling and energy flow through the major components of cold-dominated arctic and subarctic ecosystems.

The research effort during 1970 emphasized comparisons between natural and disturbed ecosystems, comparisons that were designed to establish an early understanding of how sensitive the ecosystems are to stresses and of how they adjust after being stressed. Two types of experiments involving disturbances in ecosystems have been established at the Barrow, Alaska, site: artificial and natural. The artificial disturbances consist of simulation of anticipated man-made disturbances on the temperature-sensitive permafrost terrain. These include (1) increased soil temperatures to simulate heat flow out of the tundra over a buried hot oil pipeline, (2) increased air temperature and reduction of wind speeds in the plant canopy to test the response of fauna and flora to more favorable growing conditions, (3) physical disturbance of the surface vegetation, and (4) oil spills of different intensities and duration on both land and fresh water. Validation of a precision soil-thaw model is being conducted on each treatment and on control sites.

The natural experiments simulate naturally occurring phenomena that affect the rate of nutrient and energy flow through the ecosystem (i. e., soil-plant-air processes). These include (1) clipping of vegetation to simulate increased animal grazing, (2) mulching of natural plant litter to simulate accumulation of organic matter, and (3) fertilization of both terrestrial and aquatic systems.

A variety of physiological processes are being measured on sites for experiments of both types. The processes include plant and animal productivity, microbial activity, life cycles of insects, and soil and air temperature regimes.

Each disturbed site is being compared with an undisturbed control site. The design is organized according to the four basic ecosystem components illustrated in Figure 8.

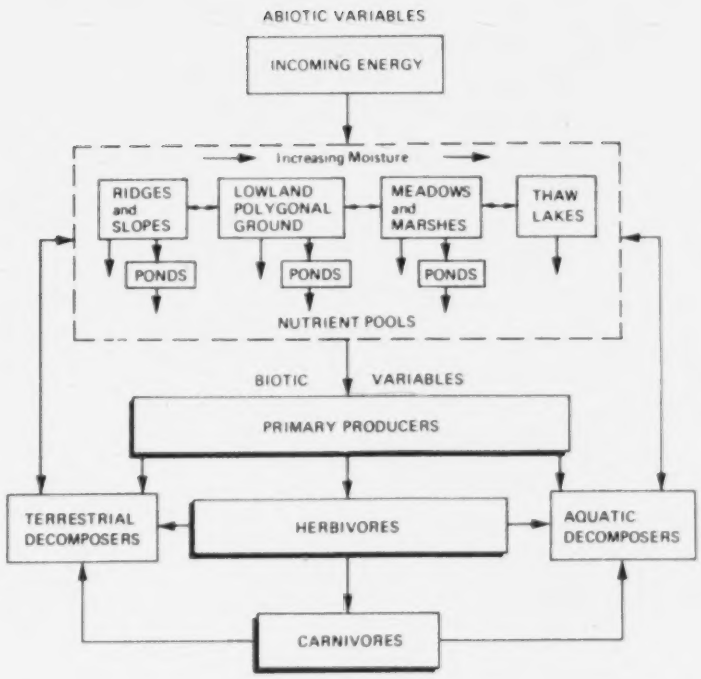

FIGURE 8 General model of wet tundra ecosystem.

Modeling activities are an integral part of the research. A primary production model for the tundra canopy is being developed at San Diego State College. A gross air-land meterological model is being developed by the Center for Environment and Man of the University of Connecticut. The U. S. Army's Cold Regions Research and Engineering Laboratory is perfecting a thaw model that will be used to predict soil temperature and depth of thaw. A general tundra ecosystem model was initiated in the fall of 1970.

Central services for the program are provided through the University of Alaska. These include chemical analyses for plant and soil samples and data processing. The data acquired in previous years from Barrow are being processed at San Diego State College. Logistic support in northern Alaska is provided by the Naval Arctic Research Laboratory, Barrow, Alaska.

J. Brown is Biome Director and G. C. West is Deputy Director. The organizational structure is shown in the following list:

A. Central program
   1. Executive
      a. Director
      b. Deputy Director
   2. Services
      a. Administrative
      b. Data processing
      c. Data analysis
      d. Data banks
      e. Analysis and modeling
      f. Sample analysis
      g. Editorial

3. Scientific coordination
   a. Producers
   b. Consumers
   c. Microbiology
   d. Nutrient flux
   e. Abiotic
   f. Aquatic
   g. Biome-wide
   h. Analysis and modeling
   i. National, international

B. Research program
   1. Intensive site studies
      a. Producers
      b. Consumers
      c. Decomposers
      d. Abiotic
      e. Aquatic
   2. Biome-wide studies
      a. Arctic and alpine, Alaska
         (1) Producers
         (2) Consumers
         (3) Decomposers
         (4) Abiotic
      b. Alpine, Colorado
         (1) Producers
         (2) Consumers
         (3) Decomposers
         (4) Abiotic

RESEARCH METHODS AND PROGRESS

Field studies in Alaska were initiated in June 1970. About 100 scientists and technicians were involved.

In order to analyze the great amount of data emanatting from these studies, a central data-processing system has been established at the University of Alaska. Centralized laboratory analysis and data processing provide rapid turnaround of statistical reports, samples, and data.

Data storage facilities have been developed for research projects that were active at Barrow, Alaska, over the last 25 years. A summary data report was published in July 1970. The Barrow data have been synthesized into a word model, or description, of the Barrow site. The following model, constructed by project participants, is being continuously refined:

The arctic tundra near Barrow, Alaska, encompasses a complex of habitats arrayed along a moisture-dominated gradient. Vegetation and soils are distributed along micro-, meso-, and macro-environments according to type and size of polygons, regional relief, and land form type. These range from upland meadow communities (arctic brown and upland tundra soils) to wet meadow and marsh types (meadow and bog soils) to emergent aquatics (hydrosols) and open water in small ponds and lakes. Ponds, an integral aspect of all principal habitats, show various stages of succession resulting from both filling and erosion. Large shallow lakes occupy 30% of the area north of 71° latitude. These vegetation, soils, microrelief and aquatic environments form a complex mosaic which influences plant productivity and animal population and diversity throughout the year. Ridges, polygon tops, and slopes commonly contain in decreasing order of occurrence *Carey aquatilis, Petasites frigidus, Salix pulchra, Arctagrastis latifolia, Poa arctica, Luzula confusa, Salix rotundifolia,* and *Eriophorum scheuchzeri. Dupontia fisheri, Carex aquatilis, Eriophorum anqustifolium* and *E. scheuchzeri, Petasites frigidus,* and *Poa arctica* occur in meadows and wet polygonal troughs. *Arctophila fulva* is found in shallow ponds.

Primary production is controlled by a combination of temperature, soil moisture, day length and nutrient supply. The more productive habitats on micro- and meso-scales are near the wetter end of the soil moisture gradient (meadows and polygon troughs). All habitats are controlled by the presence of permafrost (0° C ground temperature or colder) near the surface throughout the growing season. Especially significant to the amount of seasonal primary production are the climatic conditions of the first two or three weeks of the growing season and the previous summer's stored reserves and climate. Superimposed on this are fluctuations in nutrient cycle. On all terrestrial sites, but particularly on the wetter meso-sites, production is directly influenced by delayed effects of decay of clipped plant debris and fecal remains. It is hypothesized that the availability of nutrients to plants for growth is modulated by the lemming population through accumulation and storage of certain elements (N, K, P) in, and their ultimate release from, fecal and other dead organic matter.

Long-term rates of total decomposition in most of the habitats are approximately equal to production; there is no net accumulation of organic matter. Initial organic matter accumulation on drained lake beds is rapid. Based on evidence, depth of thaw measurements, and the absence of widespread organic terrain, organic accumulation and decomposition under uniform climatic conditions are assumed to reach a steady state within a relatively short period (presumably less than 100 years). A dominant acceleration effect in the decomposition process is the amount of standing dead plant matter prostrated by lemming grazing.

Photosynthesis on a daily basis is efficient due to the long photoperiod and generally low temperatures. During the "night," however, and particularly in the lower levels of the canopy, carbon dioxide uptake is limited by the availability of light. Grasses all show a high carbon dioxide compensation concentration, a pronounced oxygen inhibition, and low light requirement for saturation. Within species, photosynthesis serves as a function of leaf position, age, and season.

Prominent saprovores are dipterous larvae, collembolans and oribatid mites. Although the rate of organic decomposition is slow, wetter habitats show higher rates of nutrient loss through decomposition compared to better-drained, drier habitats. Microbial activity appears to be several orders of magnitude below that of lower latitude wet ecosystems and, furthermore, is confined to the upper 10 centimeters or so of the soil.

There are low numbers of thermophilic bacteria in most arctic soils. Mesophilic micro-organisms are greatest

in numbers when the soil is frozen and drop sharply once the summer thaw occurs. Psychrophilic bacteria increase in numbers during the summer. Limited metabolic activity also occurs during the summer.

Important for the assessment of production on tundra is the distinction between aboveground and underground components of plants. Biomass ratios below to above are of the order 5:1 or greater. Annual production rates below to above are approximately equal.

Annual production rates for the tundra ponds and the lakes studied are very low compared to most temperate-zone water. Many of these small ponds receive seasonal influxes of organic matter (clippings, faeces, soluble organic), especially during the spring runoff. During the summer, thermal erosion of organic-rich permafrost also contributes to lake and pond filling. Approximately 25% of the total seasonal lake production occurs beneath the ice before and after the spring thaw and after freeze-up. Production appears limited by a short growing season, low solar intensity during the growing season and nutrient deficiencies, especially for phosphorus.

Plant consumption is dominated by the brown lemming (*Lemmus trimucronatus*), which utilizes standing living tissue on a year-round basis. Other vertebrate herbivores typical of tundra elsewhere are here negligible (e. g. a second microtine, *Dicrostonyx;* caribou; geese) or absent (ground squirrels). The herbivory of arthropods is probably lower than in other ecosystems. The vegetation-lemming interaction is cyclic on a "short-term" basis, the period being three to five years.

One type of carnivory is conspicuously associated with the lemming cycle, with several bird and mammal predators present in significant densities. These include jaegers, owls, and gulls (summer active), and weasels and foxes (active year-round). Other carnivory is that of predators on insects, mainly birds but also including shrews, arachnids, and other arthropods. Most conspicuous is the carnivory of shorebirds which is concentrated on *Diptera* larvae.

Dominating all terrestrial and aquatic processes is the shortness of the growing season, varying between 45 and 90 days. Short growing season is partially compensated for by uninterrupted diurnal light.

Perturbation studies have stressed the system in such a way that physical and biological responses are evident. Preliminary analyses indicate different species sensitivities to oil spills, a marked growth response as a result of increased air temperatures, and increased production as a result of fertilization, especially with phosphorus. Responses associated with older physically disturbed areas appear to be increased rates of nutrient and energy flow, since production is frequently seen to be high while amounts of standing dead and litter are low. All these are accompanied by an apparently enhanced activity of microbial decomposition.

APPENDIX A: PUBLICATIONS

Brown, J., F. A. Pitelka, and H. N. Coulombe. 1970. Structure and function of the tundra ecosystem at Barrow, Alaska: a word model, p. 41–71. *In* Proceedings of Conference on Productivity and Conservation in Northern Circumpolar Lands, Edmonton, Alberta, Canada, Oct. 15–17, 1969. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland.

Coulombe, H. N., and J. Brown. 1970. Analyses of the structure and function of the wet tundra ecosystem at Barrow, Alaska. Abiotic data report, 1965. Bureau of Ecology, San Diego State College, San Diego, Calif.

Brown, J., and G. C. West. 1970. Tundra biome research in Alaska: the structure and function of cold-dominated ecosystems. Tundra Biome Report 70–1. U.S./International Biological Program.

APPENDIX B: PARTICIPANTS

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F. A. Pitelka, Department of Zoology, University of California, Berkeley (herbivore populations)

A. Schultz, Department of Forestry, University of California, Berkeley (pedology; nutrient cycling)

L. L. Tieszen, Biology Department, Augustana College, Sioux Falls, S. Dak. (photosynthesis; primary production)

K. Van Cleve, Department of Forestry, University of Alaska, College, Alaska (nutrient cycling; pedology)

G. E. Weller, Geophysics Department, University of Alaska, College, Alaska (micrometerology)

G. C. West, Institute of Arctic Biology, University of Alaska, College, Alaska (Deputy Biome Director; herbivore populations)

TROPICAL FOREST BIOME

Biological productivity levels in tropical forests are among the highest known, although soil nutrient levels

are extremely low. Studies of tropical forests are important for two main reasons:

- These forests are being rapidly destroyed by logging and by slash-and-burn agriculture. The destruction often results in a near-desert, because the soil nutrients are removed with the trees.
- Knowledge of tropical forests is essential to understanding the ecosystems of the world. The forests represent extremes for many environmental and biological parameters.

The research design will be similar to those outlined for the other biome studies in the analysis-of-ecosystems program.

Several organizational and planning meetings were held during 1969. Site surveys have been made in Central and South America. A variety of sites are available in Guatemala, Costa Rica, Panama, Colombia, Venezuela, and Puerto Rico. U.S. groups interested in cooperation with the IBP are working with scientists from these countries.

The Biome Director is H. T. Odum, Department of Environmental Engineering, University of Florida, Gainesville. Members of the steering committee are as follows:

Richard S. Cowan, Smithsonian Institution, Washington, D.C.
R. S. Davidson, Battelle Memorial Institute Columbus Laboratories, Columbus, Ohio
Troy C. Dorris, Reservoir Research Center, Oklahoma State University, Stillwater
Frank B. Golley, Institute of Ecology, University of Georgia, Athens
Thomas E. Moore, Museum of Zoology, University of Michigan, Ann Arbor
Jack T. Spencer, The Organization for Tropical Studies, Inc., North American Office, South Miami, Fla.
F. H. Wadsworth, Institute of Tropical Forestry, Forest Service, U. S. Department of Agriculture, Rio Piedras, Puerto Rico

Biological Productivity in Upwelling Ecosystems

The major features of an oceanic ecosystem are determined for many regions by the vertical mixing rate, that is, by the rate at which nutrient-depleted water in the eutophic zone is replaced by nutrient-rich water from below. In tropical and subtropical regions these rates are often low; as a result, there is little biological productivity and blue water. However, along the west coasts of the continents the surface water is driven offshore by the trade winds and is replaced by deep water. The term "coastal upwelling" is applied to this condition.

Regions affected by coastal upwelling are highly productive, often supporting large fisheries. An understanding of the dynamics of production in these regions would contribute to many marine activities, including management of fisheries and aquiculture, pollution control, and artificial upwelling.

The Program Director is Richard C. Dugdale.

OBJECTIVES

Objectives are:

- To obtain sufficient quantitative understanding of the structure and dynamics of upwelling ecosystems to allow prediction of the consequences of perturbations of these and other marine ecosystems when these changes result primarily in enhanced circulation of nutrients into lighted regions of the sea
- To apply the theoretical concepts so obtained to pilot aquicultural projects
- To construct a simulation model of the Peruvian anchovy fishery, incorporating the dynamics of the nutrient concentration and primary productivity

RESEARCH PLANS

The program encompasses scientific activities in three categories:

- Oceanographic cruises—to Peru in 1969 and to the Mediterranean in 1970
- Projects—one on construction of a simulation model and one on applications to aquiculture
- Conferences and symposia

Information obtained from the cruises is vital to the functioning of the projects on which activity is expected to focus in the later phases of the program.

Significant contributions already have been made to this program by the cooperating Mediterranean laboratories. The arduous task of obtaining and analyzing the phytoplankton data has been undertaken by personnel of the Instituto de Investigaciones de Pesqueras in Barcelona. A program on ^{15}N productivity measurements in the Mediterranean by the Station Marine d'Endoume in Marseille is continuing as a result of participation in the Peruvian cruise. Several Greek scientists are expected to participate in the Mediterranean cruise. The Greek scientists are from the Greek Hydrographic Service, the Democritos Nuclear Research Center, and the Department of *Botany of the University of Athens.*

Opportunities for exchange of personnel between laboratories are inherent in the upwelling program. For example:

- Facilities are being made available at the Instituto de Investigaciones Pesqueras in Barcelona.
- A visiting lecturer program is in effect at the Station Marine d'Endoume in Marseille.
- The Progam Director has been invited to lecture in Greece on elementary simulation modeling techniques.
- A graduate student from the United States will work several months at the University of Athens, where a program on plant protein production is under way.

CRUISES

The program has been designed to be truly international and yet limited in scope and geography so that important basic information can be obtained in a relatively short time with a modest expenditure of funds.

Two contrasting areas have been selected: the Peruvian coastal upwelling system and the Mediterranean Sea. The

importance of the Peruvian area arises from the intense upwelling and the associated anchovy fishery. The Mediterranean, in contrast, is impoverished in nutrients but supports a fishery of importance to the surrounding countries. Little is known of the circulation of nutrients in the Mediterranean, but local areas of enhanced vertical circulation occur that are vital to the maintenance of biological productivity.

The technique of applying identical methods to contrasting environments, a highly effective means of studying ecological systems, will be exploited fully.

Scientists from the United States, Peru, France, Greece, and Spain are participating in the program.

SIMULATION MODEL PROJECT

The simulation model project is based at the University of Washington, Seattle, where courses in simulation techniques are taught at the Center for Quantitative Science and in the Department of Oceanography. The project supports travel and maintenance for investigators who wish to go to the University of Washington to learn simulation and computer techniques or to work on a model.

Since 1963, several commercial fisheries have used large-scale digital computer simulation models to evaluate biological and economic consequences of various management policies, but there has been no previous attempt to construct a simulation model for the Peruvian anchovy fishery. Detailed analytical models have been used to estimate equilibrium yield and to study the recruitment processes of the anchovy. The biological statistics collected for these analytical models provide a data base for constructing a comprehensive simulation model of the anchovy stocks.

Past attempts by oceanographers and fisheries scientists to construct models of upwelling ecosystems have been artificial and oversimplified. Many factors, particularly the lack of well-coordinated fisheries and oceanographic studies of marine ecosystems, have obstructed progress in this area. Recent developments in simulation modeling on digital computers present new opportunities for constructing quantitative models of marine ecosystems.

AQUICULTURE PROJECT

Efficient aquiculture requires prediction and control of quality and quantity of the biological material being produced. An important step is to control the rate of primary production and the species composition of the algae in photosynthetic systems.

A neglected approach is to use chemostat techniques wherein populations of microorganisms are held in a reactor under nutrient limitation that controls the rate of biological production. In a true chemostat, nutrient medium is fed into the reactor at a constant rate, and medium from the reactor containing the organisms is expelled at the same rate. In a chemostat at steady state, the growth rate of the organisms is set by the feed rate and the concentration of the organisms is set by the concentration of limiting nutrient in the feed. The productivity is regulated by the amount of incoming limiting nutrient.

The chemostat technique shows great potential for use in some phases of aquiculture, because control of production rate and species composition is possible. However, chemostats normally run under closely regulated operating conditions, including temperature, contamination, and light in the case of algae. The similarity between chemostat conditions and those of phytoplankton populations in the tropical and subtropical oceans suggests that it might be possible to approach the problem of algal production in ponds and lagoons with chemostat procedures. Since significant departures from the rigorous conditions of true chemostat operation would occur, these experimental enclosures probably should be considered quasichemostats.

The first successful attempt to operate algal quasichemostats was made by two students in a phytoplankton ecology course at Friday Harbor Laboratories in 1968. They used plexiglas reactors with a volume of roughly 100 liters and water from the laboratory seawater system. Flow rates, nutrient concentration in the seawater feed, and light conditions varied considerably. They were able to attain a quasi-steady-state in which nutrient control by silicate was clearly evident. The flow rates were set to give doubling times of about 24 hours in one reactor and about 36 hours in the other; both were initially seeded from the contents of a net tow from surface water. Most added species washed out at these high flow rates, and the ultimate populations were about as follows: Skeletonema costatum, 90 percent; and 6 species of Chaetocerus, 10 percent.

These results warrant further investigation into the characteristics of "open-sky quasichemostats." It is planned to repeat the Friday Harbor experiments during the anchor station on the Second *Thompson* cruise off the coast of Peru.

The extent to which the chemostat system would have immediate value in aquiculture would depend on its adaptability to large containers, tanks, and eventually pools, and on its independence of artificial radiation and temperature control. Long-range aquicultural uses include the application of chemostat principles in the utilization of artificially upwelled deep water and use of treated sewage or other pollution products in natural or man-made enclosures or impoundments.

CONFERENCES AND SYMPOSIA

The conferences are required to maintain direction and momentum during the entire period. The more formal symposia are to be held later for the dissemination, discussion, and synthesis of results that are well beyond the preliminary stage.

RESEARCH METHODS AND PROGRESS

CRUISE

In early 1969 a cruise was made to the coast of southern Peru. A rectangular grid 15 miles long and 30 miles wide was established about 5 miles off the Peruvian coast (see Figure 1). The grid area was studied intensively during two visits of the *Thompson* and on three shorter visits of the *Gosnold*.

During the first visit, an intensive survey was made of the grid area and three strings of current meters were set. Routine data were processed by the shipboard data reduction system that includes a computer and an on-line data acquisition system. Automatic sampling instruments measured the temperature, salinity, and the concentration of chlorophyll, nitrate, and silicate of water pumped from three meters depth while the ship passed over a predetermined path on the survey grid. Also incident radiation, wind speed and direction, and ships heading and direction were measured and recorded. From these data maps were produced that showed the distribution of temperature or chlorophyll or the two nutrients. About 24 hours of sampling time were required to produce maps of the entire region. Maps of smaller areas were made during the night. These maps were valuable during the second visit because they were used in planning the acquisition of water samples for experimental purposes.

Groups of scientists collaborated on various problems. Information was exchanged during evening seminars. Before the end of the cruise most of the data were reduced to a form suitable for initial analysis.

Physical Oceanography

All the current meters and the wind instrument carried on the two strings recovered at the end of the first visit were found to have functioned while in place. All records have been read and processed. The results show that the currents at depths greater than 25 m were to the southeast, that is, parallel to the coast. Once during the cruise this southerly flow ceased, and a temporary, small northerly component developed. The wind data showed clearly that although there were large fluctuations in velocity, the direction was consistently from the southeast, that is, parallel to the coast and directly opposite to the flow of water at the 25-m depth.

These findings, together with the results of a number of surface drogue experiments, give a consistent picture of an advancing and retreating front in the region studied. The front advances to the north as the winds blow more strongly and retreats to the south as the wind stress is relaxed. Surface flowing water is accelerated to the left and tends to move offshore to be replaced by southerly flowing water from about 25 m, which is simultaneously accelerated in the onshore direction. It is likely that bottom topography has some effect on this simplified model of water movement. The persistently low temperatures along lines 6 and 8 (Figure 1) during most of the study are striking and may be caused by a submarine ridge that extends out from the shoreline.

Nutrient Circulation

Standard productivity stations were made throughout the survey and included the measurement of primary productivity by ^{14}C uptake, chlorophyll and light measurements, phytoplankton sampling, and the measurement of nutrient demand through measurements of ^{15}N-labeled nitrate and sometimes ammonia. The measurement of nitrate demand by the phytoplankton population at all the survey stations makes it possible to compute an average upwelling velocity if the nitrate content of the upwelling source water is known. A preliminary estimate of the upwelling rate by this means is about 0.5 to 1 m per day.

During Leg 2, an effort was made to determine the kinetics of phytoplankton nutrient uptake. These studies required the cooperation of several scientists. Five scientists studied nitrogen uptake and three studied silicate uptake.

The study of nitrogen uptake included the study of nitrite, nitrate, and ammonia. Reaction rates of nitrate and ammonia uptake were obtained as functions of light intensity and nitrate and ammonia concentration. The effect of light intensity on nitrate and ammonia uptake can be described by the Michaelis-Menton expression with great accuracy. The constants for the Michaelis-Menton expression do not vary significantly from the 100 percent light level to the 10 percent light level. At high nitrate concentrations, nitrate uptake was found to be proportional to nitrate concentration. Measurements made in a shipboard chemostat have been used to derive a quantitative expression for the suppressive effect of ammonia on nitrate and nitrite uptake.

Nitrate uptake was also studied in relation to nitrate reductase activity. Two scientists collaborated in standardizing their procedures for measuring the activity of nitrate reductase. Their subsequent studies revealed a

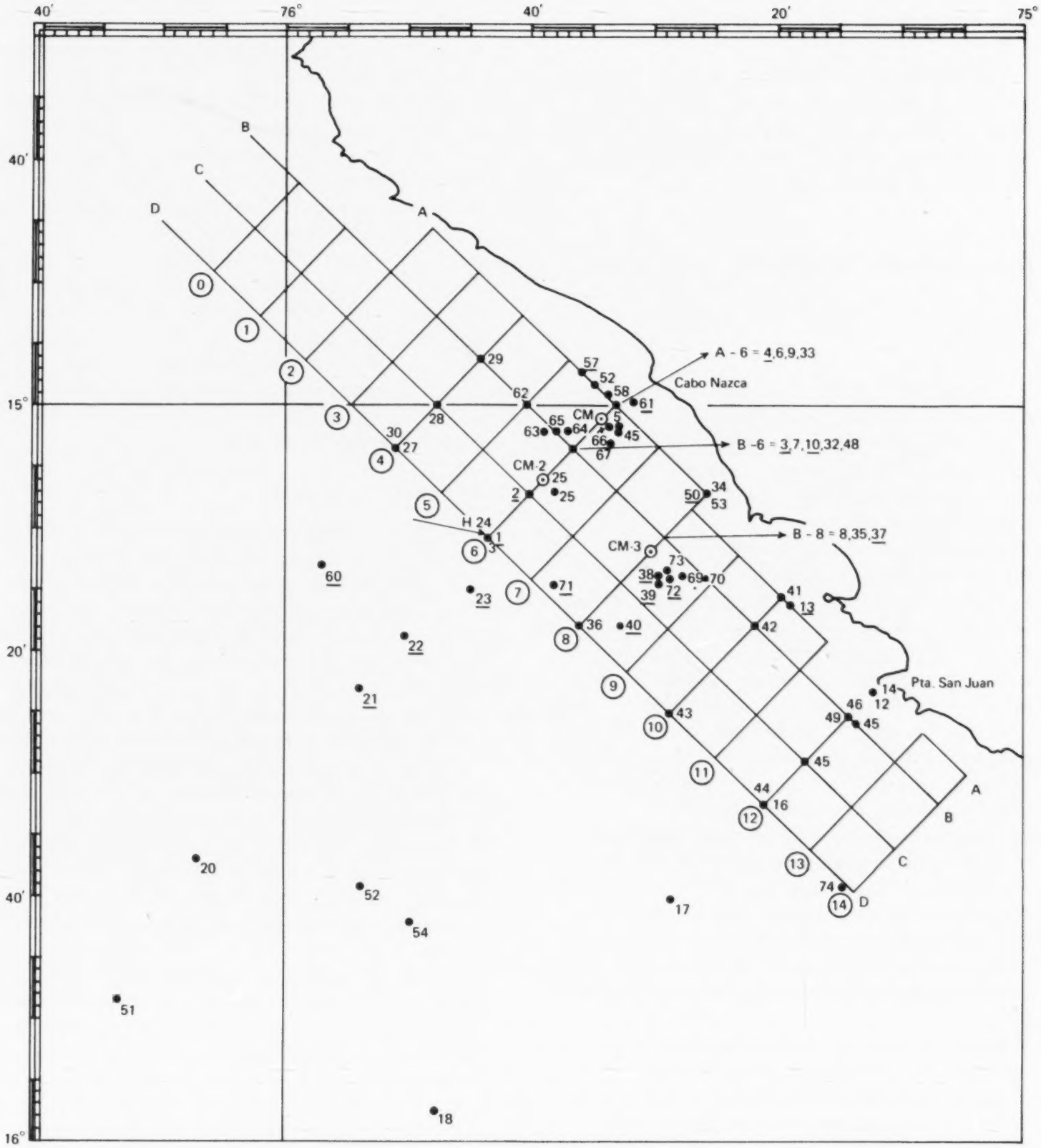

FIGURE 1 Cruise track for R/V *Thompson* 36. The letters A, B, C, and D designate lines of grid parallel to the coast; CM designates current meter locations; circled numbers designate lines normal to the coast; other numbers designate hydrostations.

strong daily cycle in nitrate reductase activity in the phytoplankton population. A comparison of the nitrate reductase activity with nitrate uptake suggests that a second nitrate reductase is present that is not being measured.

A coalition of scientists studied silicate cycling. They measured the uptake of silicate by phytoplankton by using the heavy isotope ^{28}Si and by observing the rate of depletion of silicate in carboys exposed to sunlight. They also made particulate silicate measurements. The determination of isotope ratios in the particulate silicate fraction is laborious and time-consuming, and the results are not yet available. If the water is relatively stable and the phytoplankton population has been present some days, then the particulate matter has a nitrate-silicate ratio that closely matches the nitrate-silicate ratio in the water.

This similarity suggests that silicate, like nitrate, was taken up by diatom populations in amounts that were in proportion to the amounts available in the water. In the case of nitrate, it appears that nitrate reductase, an inducible enzyme, is synthesized in proportion to the amount present in the water, providing an explanation for the observed result. Finding an explanation for silicate uptake may be more difficult. Nevertheless, the information on nitrate and silicate uptake has important implications for control of the nutrient ratios in the upwelling area.

Maps of the nitrate-silicate ratio at 3 m in the study area show large differences. The differences appear to arise from (1) the depth of the upwelling water, a result of a depletion in silica relative to nitrate in the region above the pycnocline, and (2) the appearance of dinoflagellate blooms that leave silicate untouched while consuming nitrate. This ratio may be useful in assessing the depths from which the upwelling water is derived and as a means of distinguishing between diatom and dinoflagellate activity.

Although phytoplankton populations in recently upwelled water are often believed to show a lag period before normal growth takes place, the phenomenon was not observed on the *Anton Bruun* 15 or during the major part of the Peruvian cruise. Work carried out on the *Thompson* has been very helpful in explaining this apparent conflict. Factorial experiments were conducted in which various chelating agents were added to samples of seawater. The effects were assayed with ^{14}C. When localized upwelling prevailed, the recently upwelled water was chelated by naturally occurring organic compounds to such an extent that no increase in growth rates was induced in the experiments. However, when massive upwelling flooded the study area, the water was poorly chelated and higher growth rates were experimentally induced. The working hypothesis is that sufficient iron is always available in surface seawater but that its availability depends on the presence of naturally occurring chelating compounds. Presumably, the chelators are excreted by the algae themselves. These findings are consistent with the idea that during localized upwelling the water comes from shallower levels and that during large-scale upwelling the water comes from considerably deeper levels. Water from deeper levels has not been in contact with the surface recently. An anodic-stripping technique was used to directly measure trace metal concentrations and the effects of added chelators on trace metal concentrations in different water types. The results generally confirmed the hypothesis stated here.

Phytoplankton Ecology

The research on phytoplankton ecology was under the direction of a Spanish scientist and was carried out on shipboard by one of his students. A considerable number of samples were counted on shipboard, and a running account of gross species composition was made. However, most samples have been returned to the Instituto de Investigaciones Pesqueras in Barcelona for counting and analysis. During a visit with the Program Director after the cruise, plans were laid for analyzing the data and for next year's work. The productivity and hydrographic data will be used to perform multiple correlation analysis on a computer.

An important consideration in the analysis of the species composition may be the instantaneous growth rates of the population. These rates have already been computed from the data on nitrate and ammonia uptake, and another valuable contribution may be made when RNA-DNA analyses are completed.

Food Chains

Preliminary processing of the zooplankton collections has been completed at Woods Hole Oceanographic Institution. Settling volumes have been measured and the collections have been sorted into major groups. Further studies of these groups will be made. A program of laboratory culture of species of Pseudocalanus has been instituted. The zooplanktors have been carried through an entire generation. They appear to require freshly produced phytoplankton, without which the individuals die or do not produce eggs. The females produce egg snacks as rapidly as one every 2 days, and one female may produce as many as 200 new individuals in 2 weeks.

The research on excretion products as a means of distinguishing and quantifying grazing activity by zooplankton and by fish is well under way. A reliable method for the analysis of creatine in seawater was developed and used on the Peruvian cruise. Ordinarily, creatine could not be detected in seawater except under conditions of high fish concentration. In several experiments, anchovies were caught and placed in holding chambers for short periods, and analyses for ammonia, creatine, phosphate, and oxygen were made. A surprising result was that, under these conditions, ammonia and creatine were excreted in approximately equal proportions. It appears that creatine can be excreted in rather large quantities, and since it does not accumulate in seawater it follows that there is a very rapid turnover of this substance. Phosphate appears to be excreted in a definite ratio to creatine, and some preliminary calculations suggest that large schools of anchovies moving slowly through an area may markedly influence the ammonia and phosphate concentrations in the water. A secondary effect of elevated ammonia concentration may be the reduced uptake of nitrate by phytoplankton.

Urea in seawater was measured on the cruise. The anchovies used in the research just mentioned were also

monitored for urea excretion rates. The results suggested that urea, like creatine, has a rapid turnover rate in the sea.

Benthos

The benthic collections made on the *Gosnold* and the *Thompson* are being processed at the Woods Hole Oceanographic Institution. The most interesting immediate result of these studies has been the discovery of large quantities of phosphorite in some of the collections obtained in the vicinity of line 8 at 100 to 150 m (Figure 1). These deposits appear to form a pavement over the submarine ridge that extends in a direction perpendicular to the shore. The relationship between the persistent upwelling in the vicinity mentioned and the presence of phosphorite accompanied by high phosphate concentrations in the water is unknown. It is likely that these deposits are the source of anomalous phosphate concentrations found in the water near the coast and over this ridge. Further investigations of the phenomenon are desirable.

DATA HANDLING

Data Center

Virtually all the data taken during the cruise to Peru have been reduced and copies are available at the Department of Oceanography, University of Washington. A large amount of data is included in a data bank on disk files and IBM cards. Lists of these data will be drawn up and circulated along with the instructions for requesting the data from the data bank. Publication of data will be limited to the routine hydrographic and productivity reports.

Plans are also being drawn up to maintain a complete bibliography and reprint file on upwelling. This project will be computer oriented to allow rapid dissemination of references to contributing investigators.

Shipboard Computer Applications

Two shipboard computer applications are being developed. The first application is an integrated system for data acquisition, editing, analysis, and presentation. The system provides for acquisition of up to 20 variables and for graphical display of the distributions of the variables of interest. The system analyzes data from STD lowerings.

The second application is use of the computing system itself to make decisions about significant changes in the phenomena under investigation. The system would then trigger the appropriate sampling devices so that important events will not be missed and redundant data will not be collected.

Work is proceeding on a number of sampling algorithms that can be applied to the acquisition of data while cruising or to sampling any general time series. Algorithms have been developed and tested for stability under different sampling conditions. They provide sampling criteria that will be programmed into the shipboard computing system.

SIMULATION MODEL PROJECT

Two submodels are being developed—one for oceanographic processes and the other for nutrient cycling and biological productivity.

A simulation model encompassing nutrient circulation, phytoplankton production, and zooplankton grazing is being developed. This modeling effort provides a link with the fisheries-oriented group in the Center for Quantitative Science at the University of Washington.

The oceanographic processes submodel is being developed at Florida State University. The submarine topography may be highly significant in determining regions of potential upwelling. The Peruvian data should provide information useful in testing this possibility.

In October 1969, plans were made to integrate the efforts in modeling of the oceanographic processes with the modeling of nutrient circulation and phytoplankton production.

AQUICULTURE PROJECT

A battery of three algal quasichemostats were operated on the roof of the oceanography building at the University of Washington during the summer of 1969. Each was operated at a different dilution rate with water obtained from Puget Sound and held in tanks. Seeded with a plankton tow from Puget Sound, these chemostats came to equilibrium rapidly, and initial populations composed mostly of dinoflagellates were displaced by diatom populations. As in the Friday Harbor chemostats of the previous summer, the composition of the populations was a function of feed rate. The populations of the Friday Harbor experiment and of the Seattle experiments were similar in so many ways that investigators are confident of success in their efforts to grow phytoplankton with a relatively constant species composition and at a specified concentration to provide food for filter feeders.

Work on the aquiculture project will proceed at both the University of Washington and the Woods Hole Oceanographic Institution. Efforts at the University of Washington will continue to be directed toward the production of food phytoplankton of known species composition at controlled cell concentrations. These investigations will be of a fundamental nature, concerned with the control mechanisms that bring about steady state in a quasi-chemostat and with the conditions that permit a multiple-species population to exist. Plans for scaled-up versions

of these chemostats are being developed. An effort will be made to utilize the effluent populations for feeding oysters and other filter feeders. Various mathematical models will be examined, and computer simulation techniques will be used where necessary.

APPENDIX: PARTICIPANTS

On Board the R/V *Thompson**

R. Barber, Woods Hole Oceanographic Institution, Woods Hole, Mass. (PS, chelation effects on productivity)
D. Blasco, Instituto de Investigaciones Pesqueras, Barcelona, Spain (PS, phytoplankton taxonomy)
N. Borovikoff, University of Washington, Seattle (marine technician)
W. Broenkow, University of Washington, Seattle (NC, mathematical models)
W. Chernoff, University of Washington, Seattle (chemical technician)
J. Cline, University of Washington, Seattle (PO, formation of the oxygen minimum zone)
L. Conway, University of Washington, Seattle (FC, ^{15}N productivity)
C. Davis, University of Washington, Seattle (PS, quasi-chemostate)
B. de Mendiola, Instituto del Mar del Peru, Callao, Peru (FC, anchovy feeding habits)
R. Dugdale, University of Washington, Seattle (FC, ^{15}N productivity)
J. Dugdale-MacIsaac, University of Washington, Seattle (PS, nutrient limitation)
D. Enfield, Oregon State University, Corvallis (PO, current measurements)
R. Eppley, Institute of Marine Research, University of California, San Diego (PS, nitrate reductase and nitrate uptake)
J. Goering, University of Alaska, College (NC, denitrification)
O. Guillen, Instituto del Mar del Peru, Callao, Peru (FC, ^{15}N productivity)
P. Harrison, University of Washington, Seattle (PS, particulate silica)
M. Healy, University of Washington, Seattle (NC, trace metals)
L. Hobson, Woods Hole Oceanographic Institution, Woods Hole, Mass. (NC, fate of particulate carbon)
T. Hopkins, University of Washington, Seattle (PO, current measurements)
J. Kelley, University of Washington, Seattle (FC, mathematical models, data processing programs)
J. Lewin, University of Washington, Seattle (PS, *Chaetocerus*, silica)
R. Mackenzie, Woods Hole Oceanographic Institution, Woods Hole, Mass. (FC, benthic populations)
N. Margaris, University of Athens, Greece (PS, light limitation)
M. McCarty, University of Washington, Seattle (computer operator)
J. McCarthy, Institute of Marine Research, University of California, San Diego (PS, urea studies)
H. Minas, Station Marine d'Endoume, Marseille, France (FC, ^{15}N productivity)
L. Olund, University of Washington, Seattle (computer programmer)
R. Olund, University of Washington, Seattle (chemical analyst)
T. Packard, University of Washington, Seattle (PS, nitrate reductase, ammonia and phosphate regeneration)
M. Pamatmat, University of Washington, Seattle (NC, regeneration of nutrients at sediment surface)
D. Pillsbury, Oregon State University, Corvallis (PO, current measurements)
G. Rowe, Woods Hole Oceanographic Institution, Woods Hole, Mass. (FC, benthic populations)
R. Smith, Oregon State University, Corvallis (PO, current measurements)
R. Stevenson, Bureau of Commercial Fisheries, National Oceanographic and Atmospheric Administration, U.S. Department of Commerce, Galveston, Tex. (PO, observer)
C. Valarde, Hydrographic Service, Callao, Peru (PO, observer)
V. Welsh, University of Washington, Seattle (marine technician)
T. Whitledge, University of Washington, Seattle (FC, creatine excretion by anchovies)
S. Zuta, Instituto del Mar del Peru, Callao, Peru (PO, current measurements)

*Key to abbreviations: PO = physical oceanography; NC = nutrient circulation; PS = phytoplankton studies; FC = food chains.

On Board the R/V *Gosnold*

P. Clarner, Biological Oceanographer, Woods Hole Oceanographic Institution, Woods Hole, Mass. (primary production studies)
N. Corwin, Biological Oceanographer, Woods Hole Oceanographic Institution, Woods Hole, Mass. (primary production studies)
B. Frost, University of Washington, Seattle (zooplankton sampling)
G. Grice, Woods Hole Oceanographic Institution, Woods Hole, Mass. (zooplankton sampling)
T. Lawson, Biological Oceanographer, Woods Hole Oceanographic Institution, Woods Hole, Mass. (zooplankton sampling)
Carl Lorenzen, Oceanography Section, National Science Foundation, Washington, D.C. (phytoplankton studies)
R. Mackenzie, Woods Hole Oceanographic Institution, Woods Hole, Mass. (phytoplankton studies)
D. Menzel, Woods Hole Oceanographic Institution, Woods Hole, Mass. (primary production studies)
G. Rowe, Woods Hole Oceanographic Institution, Woods Hole, Mass. (phytoplankton studies)
J. Ryther, Woods Hole Oceanographic Institution, Woods Hole, Mass. (primary production studies)

Marine Mammals

From antiquity to the present day, marine mammals have been a major resource through which man has utilized the energy of marine ecosystems. While emphasis on different species has changed through history, overall utilization has increased. With the growing protein and food shortages in the world, this trend can be expected to continue.

While studies of marine productivity have been focused on the base of the trophic structure, most of the exploitation has been at the top. This exploitation has, for the most part, been heedless of biological limitations, with the result that population after population has been depleted. This has been conspicuously true of marine mammals.

Avoiding the repetition of past mistakes requires more than good intentions, however; there must also exist sound biological information about a fauna within its ecosystem. Knowledge concerning marine mammals lags a century behind that concerning terrestrial mammals. This program is an attempt to provide information about marine mammals on an ecosystem basis.

Traditional and current methods of study have emphasized population dynamics of economically valued species, too often with little ecological basis. Recent studies of behavior and physiology have emphasized the experimental animal, again with little opportunity for an ecological program.

Only a vigorous and broadly based pattern of investigations by many persons working in a wide spectrum of biological disciplines can yield an understanding that will be adequate for intelligent utilization and management of the major biological resources that marine mammals represent. Studies of distribution, productivity, systematics, behavior, and ecology must go forward simultaneously if understanding of marine mammals is to be obtained in time to serve a useful purpose. Studies will have to be expanded to integrate investigations on and in the sea as reflections of species adaptations at many levels. The International Biological Program offers an opportunity for marine mammalogists to cooperate in studies having an ecological rather than an economic base.

In 1967, the U.S. National Committee for the International Biological Program decided that a study of marine mammals should be included in the U.S./IBP and appointed a group to develop a program. This group drew up a proposed program in 1968. The National Committee and the International Marine Mammal Working Group (PM) approved the proposal in 1969.

A recent proposal requesting support for this program has been submitted. The Marine Mammal Working Group (U.S.) has organized this program.

OBJECTIVES

The objectives of this program are to provide basic information needed for rational international management of marine mammals and to encourage increased international collaboration among marine mammalogists. The program emphasizes the productivity of marine mammals within their trophic structure. Many marine mammals, especially the smaller species, reflect unusually well the patterns of primary productivity of the seas since they tend to concentrate where food resources are greatest. Further, because they must breathe air, these concentrations can be observed from the surface.

RESEARCH PLANS

CRUISES

Since the distribution of all marine organisms is highly discontinuous, it is important to study some of the areas of discontinuity in detail. In Cetacea, discontinuities seem to be related to the levels of productivity of water masses.

Cruises in the Bering Sea, in the Arctic Ocean adjacent to the Bering Sea, and in the South Atlantic Ocean (middle and high latitudes) are being planned. It is hoped that scientists from several nations will participate.

INFORMATION EXCHANGE

Publication of a newsletter for marine mammalogists is expected to begin in 1971. It will include news briefs,

notices of cruise opportunities, and items concerning recent literature.

International symposia are planned for further exchange of information and to encourage research on marine mammals. A symposium is being planned for the second year of this program to determine the status of marine mammal research and to stimulate greater participation in the field. A second symposium is planned, for the final year of the program, to measure progress and establish directions for further research. These symposia will be modeled after the First International Symposium on Cetacean Research, held in Washington, D.C., in August 1963.

STUDY CENTER

A center for processing, storing and studying specimens of marine mammals is essential to progress in the program. Such a center is planned in Washington, D.C., by the Smithsonian Institution, which is participating in the program.

The center would include a cold room for temporary storage of freshly captured specimens, a room for flensing and study, and equipment for macerating, degreasing, drying, and embalming. It would also include equipment for preparing tissue for study under microscopes.

Collections would include skulls, skeletons, soft parts preserved in fluid, frozen specimens, and a variety of anatomical, histological, and parasitological specimens.

MANAGEMENT STRUCTURE

The program is guided by a Marine Mammal Council of 11 members, headed by a program director. The council will develop the marine mammal study center, plan conferences and symposia, and coordinate various activities, including field work, processing and storage of materials, and reporting to marine mammalogists. Council members are:

G. Carleton Ray (Program Director), The Johns Hopkins University, Baltimore, Md.
Kenneth S. Norris, Oceanic Institute, Oahu, Hawaii
Charles O. Handley, National Museum of Natural History, Smithsonian Institution, Washington, D.C.
William E. Schevill, Woods Hole Oceanographic Institution, Woods Hole, Mass.
George A. Bartholomew, Jr., University of California, Los Angeles
John J. Burns, Alaska Department of Fish and Game, Nome
William C. Cummings, Naval Undersea Research and Development Center, San Diego, Calif.
William E. Evans, Naval Undersea Research and Development Center, San Diego, Calif.
Francis H. Fay, Arctic Health Research Center, College, Alaska
Karl W. Kenyon, U.S. Fish and Wildlife Service, Seattle, Wash.
Clayton E. Ray, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Dr. G. Carleton Ray, Dr. Norris, Dr. Handley, and Mr. Schevill make up the Executive Committee of the Council. Suzanne M. Contos is Executive Secretary.

RESEARCH METHODS

The program is in three parts:

- Regional studies, including the relationships between cetacea and current systems of the Pacific, the distribution and abundance of South Atlantic cetacea as correlated with primary productivity, and the biology of Bering Sea harbor seals and relationships with other ice-inhabiting pinnipeds
- Studies of marine mammals of special interest, including the social behavior of otariids as an influence on productivity and the reproductive behavior of the gray whale
- New techniques, including population analyses of large cetacea through acoustics and the use of telemetry for tracking and behavior studies of marine mammals

Origin and Structure of Ecosystems

The fundamental biological question that this program is asking is whether two very similar physical environments acting on phylogenetically dissimilar organisms in different parts of the world will produce structurally and functionally similar ecosystems. If the answer is no, there cannot be any predictive science of ecology. In effect, knowledge acquired from studying a given ecosystem cannot be applied to an anologous ecosystem, unless similar physical environment indeed means similar ecosystem.

This program has three components. One is a study of ecosystems that have evolved separately under similar physical environments to ascertain whether they have similar structure and ecological niches. Another is a study of evolutionary and ecological diversity in selected groups of organisms, particularly amphibians of the New World. The third component is a study of an isolated island ecosystem (Hawaii). It will be concerned with the diversity and stability of isolated ecosystems and with the effect of isolation on structure.

Common to these three subprograms is the intent to integrate studies of ecology with studies of evolution to investigate ecosystem structure and development. Ecological aspects considered are species diversity, niche utilization, and life form interaction. Evolutionary aspects considered are the causes, mechanisms, and rates of speciation.

The research in this program requires study of ecosystems in widely separated areas. Hence, this program has developed as an international effort involving scientists in many American countries.

OBJECTIVES

Objectives are:

- To investigate ecological systems with similar physical environments and determine the degree of ecological relationship between the species
- To discover how much of this similarity is attributable to parallel evolution of relatively closely related taxa and how much is attributable to convergence of distantly related taxa
- To improve understanding of ecological diversity by studying the evolutionary history and the phylogenetic affinity of a few taxa within given phylogenetic groups
- To determine the relationships of stability, diversity, and productivity in these ecosystems
- To determine the relationships between native and exotic plants and animals, and man's role in the introduction and establishment of weedy organisms
- To establish the interrelationship between ecosystem structure and human culture and economy

RESEARCH PLANS

STRUCTURE OF ECOSYSTEMS

The research strategy for this subprogram is to compare two sites for each biome. The biomes to be considered are the thorn scrub and Mediterranean scrub. One biome site is in South America; the other is in North America.

For the thorn scrub vegetation, comparisons are being made between the Silver Bell Bajada site, near Tucson, Arizona, and one near Andalgala in the state of Catamarca, Argentina. For the Mediterranean scrub, comparisons are being made between Cuesta la Dormida, province of Santiago, Chile, and Corte Madera Valley of the Laguna Mountains, California.

Field and laboratory work is designed to compare the environments and to compare the ecosystems. Elements of the environment to be considered are macroclimatic and microclimatic patterns, soil genesis (including soil micromorphology), geological history and paleohistory, and land-use patterns. Elements of the ecosystems to be considered are structure (including physiognomy, morphology, species number and diversity, life forms, niche patterns, and pattern of distribution of individuals in the community), floristic and faunistic similarities and differences, and function (including phenological cycles, regulatory mechanisms, succession patterns, energetic and biochemical pathways, adaptive modes, and species interactions).

EVOLUTIONARY AND ECOLOGICAL DIVERSITY

The objective of this subprogram is to improve understanding of the evolutionary history and ecological diversity of a few taxa. The approach is multinational and multidisciplinary. Anuran amphibians of the New World are being studied by cooperating teams of North and South American workers.

Anuran amphibians are most diverse in the tropics, and little ecological or taxonomic information about them is available. Consequently, much fundamental ecological and taxonomic research is necessary.

Two types of studies will be conducted: ecological and phylogenetic. Intensive ecological studies in ecologically different areas will include measurements of larval and adult microdistribution, measurements of species diversity, seasonality, trophic position, population size and structure, reproductive cycles, isolating mechanisms, and niche breadth. The standardized techniques used in these studies will be comparable with those used in recent major studies in the Old World tropics.

Neotropical anuran amphibians are being studied with respect to external morphological features of adults and tadpoles used in taxonomy; osteological characters and their importance in the determination of supraspecific relationships; sperm morphology; karyotype, including number and structure of chromosomes; biochemical features of skin, blood, and other systems; life histories; premating isolating mechanisms, especially mating calls; and experimental hybridization.

The phylogenetic and ecological studies complement each other. Many data of interest to the group concerned with phylogeny will derive from the site studies, and the phylogenetic group will provide the ecologically oriented group with estimates of phyletic distance between the animals they are studying.

The major reasons for emphasizing frogs (order Anura) in the study are as follows:

- Because of their abundance and their important position in the food chain, frogs are a highly significant group in many ecosystems.
- Frogs are easily collected and easily maintained in the laboratory.
- A multidisciplinary approach to anuran research is possible because of the wide variety of techniques that have been found successful, and this approach greatly increases the reliability of phylogenetic conclusions.

ISLAND ECOSYSTEM STABILITY AND EVOLUTION

This subprogram is concerned with tropical ecosystems that evolved in isolation in the midst of the Pacific Ocean (Hawaiian Islands). These ecosystems contain the same principal environmental components that are found in many mainland tropical ecosystems, but their biotic component is extremely restricted in origin. This original biotic component has evolved into a diversity of its own. To the endemic diversity of the island ecosystems a non-evolutionary diversity has been added through man-introduced biota. A competitive struggle is going on in many ecosystems that threatens to destroy the endemic diversity in several of the island habitats.

This subprogram seeks to discover the fundamental causes of the competitive struggle in order to gain insights into the stability-fragility relations of those native ecosystems where the direct interference of man has been held to a minimum.

This subprogram consists of intensive studies of a few selected ecosystems, comparisons of ecosystems along well-defined environmental gradients, and studies of endemic populations. The ecosystems studied intensively are those whose species composition and structure have been the result of island evolution. The intensive ecosystem studies are to determine the composition and structural variation of the ecosystem, the direction of the ecosystem's development, and the rates of population change.

Ecosystems are compared along environmental gradients in order to study the factors responsible for changes in ecosystem stability. These studies will investigate the nature of the relationship between species diversity and ecosystem stability. The interrelationship of ecosystem structure, dominant organisms, and ecosystem structure along an environmental gradient will also be investigated.

Endemic populations that successfully adapted to island ecosystems will be studied to determine the mechanism of adaptation. Specific points to be considered are the factors that determine success, rates of speciation, and degree of speciation.

MANAGEMENT

This program is directed by W. Frank Blair. The organizational structure is shown in the following list:

Structure of ecosystems (Otto T. Solbrig)
- Desert scrub project (Jorge Morello and Otto T. Solbrig)
- Mediterranean scrub project (Francesco di Castri and Harold Mooney)

Evolutionary and ecological diversity (Craig E. Nelson and Sheldon Guttman)

Island ecosystem stability and evolution (Andrew J. Berger, J. Linsley Gressitt, and Dieter Mueller-Dombois)

RESEARCH METHODS AND PROGRESS

STRUCTURE OF ECOSYSTEMS

Desert Scrub

During early 1971, studies will begin at the site near Andalgalá. In late 1970, transects will be set up and a base map, describing the vegetation, will be prepared.

Several preliminary studies have been made of the biota of the semidesert areas of Argentina. These projects, which contribute to the work at Andalgalá, are a remote sensing flight and studies of subandean insects, animal niches, genetics of *Bufo arenarum*, and genetics of thorn scrub.

Previous work by Morello with vegetation of the Argentine Monte provides a starting point for the analysis of the Argentine component of the two convergent thorn scrub systems being compared. A remote sensing flight by the National Aeronautics and Space Administration (Earth Resources Division Mission No. 97) over northern Argentina from Formosa to Salta on July 19, 1969, provided invaluable data for the vegetational aspect of the study. The flight was a cooperative effort of NASA and of personnel of the Instituto Nacional de Tecnologia Agropecuaria (INTA). Instrumentation included two RC18 mapping cameras (Ektachrome MA Aerographic and Ektachrome IR Aerographic film), one multiband KA62 camera system (three images with Plus-S Aerographic film at wavelengths of 477, 530, and 517), one camera system with infrared film at 750, and a thermal two-channel mapper. An Auxiliary Data Annotation System provided all necessary information about date, time, altitude, ground speed, and the like.

INTA personnel are responsible for "ground truth" for the remote sensing data in Argentina and for interpretation. Complete sets of the data collected in Argentina have been provided by NASA to the INTA organization in Argentina and to the University of Texas in Austin.

Field work leading to a comparison of ecological niches of animals is most advanced for lizards and freshwater fishes. Richard D. Sage has completed 3 years of field work in western Argentina and has identified a series of ecological equivalents of North American species among the lizards. He has concentrated on detailed studies of the ecological life history of a few species (*Liolaemus darwini* = *Uta stansburiana* and *Phymaturus palluma* = *Sauromalus obesus*) but has also worked extensively with other species. William S. Birkhead, who terminated a year and a half of field work in early 1970, has been working with the freshwater fishes of the streams that drain from the Sierra Córdoba. Preliminary results reveal striking similarities in the ecological niches of these fishes and those of the comparable North American area. Streams at the Cafayate site resemble those of the comparable North American area in having a depauperate fish fauna.

Working on the population genetics of *Bufo arenarum*, Terry Matthews collected breeding stocks during his field work in Argentina in the fall of 1968 and from these did laboratory crosses to learn the genetic basis for the behavioral trait he is studying in wild populations. He did additional field work from September to December 1969. In 1969, John Kirsch and an Australian coworker started several months of collecting marsupial material in northern and western South America. In the fall of 1969, Jerry Boggs, graduate student supervised by Don Hunsaker, began a population study of *Marmosa* and *Caluromys* in Minca, Colombia, in the Santa Marta Mountains, where living research facilities were provided by the Instituto de Recursos Naturales, an agency of the Colombian government.

In 1969, research on the genera *Larrea* and *Glandularia*, and work on *Prosopis*, was initiated by Otto T. Solbrig of Harvard University and Juan H. Hunziker of the University of Buenos Aires.

The first phase of the program of crosses between North and South American species of *Glandularia* has been completed and some of the results have been published. It was demonstrated that the North American hexaploid species *G. elegans* is a segmental allohexaploid of diploid South American species. Working independently and using cultivated species, Khoshoo in India was able to arrive at similar results in regard to the North American hexaploid *G. canadensis*, which he crossed with the cultivated *G. hybrida*, a species of South American origin. Crosses between several North American species by Solbrig, including *G. elegans* and *G. canadensis*, indicate that they are closely related cytologically. It is therefore valid to hypothesize that the North American species are derived from South American ancestors. Whether the North American species originated in South America, migrated northward, and later became extinct in the south, or whether the South American species once grew in North America and there gave rise to the polyploid species, is impossible to tell. The situation in *Glandularia* appears to be unique, since it cannot be explained by a single migration event as in the case of other disjunct distributions involving interfertile plants.

The genus *Larrea* is represented in South America by four species, three of which are shrubs 1 to 3 m high: *L. cuneifolia*, *L. divaricata*, and *L. nitida*. They are distributed from Peru to Chubut and from Chile to Buenos Aires. The fourth species is a woody chamaephyte (*L. ameghinoi*), whose range extends in Patagonia from Neuquen to Chubut.

Cytological studies done by Juan H. Hunziker have shown that *L. divaricata*, *L. nitida*, and *L. ameghinoi* are diploid (n=13), whereas *L. cuneifolia* is a tetraploid (n=26).

It was possible to locate and study in detail areas where all four species meet. Hunziker *et al.* (1969)* found that in such situations hybrid swarms are formed from hybridization between *L. ameghinoi* and *L. nitida* on one hand and *L. nitida* and *L. cuneifolia* on the other. Studies of seed protein and flavonoid patterns have been performed or are in progress on all the South American species and on the various ecotypic forms of the North American species, *L. tridentata*.

Vuilleumier (1969)* has written a biosystematically oriented revision of the South American species of the genus *Perezia*, a genus with a disjunct North American-South American distribution.

In January 1968, the entomology section of the Instituto Miguel Lillo, in Argentina, initiated a 5-year study of the insects of the subandean biota (Southern Creosote Bush Province). Financing of this project is shared by the Instituto Miguel Lillo and the Consejo Nacional de Investigaciones Cientificas y Tecnicas. The principal investigators are Abraham Willink (Hymenoptera), Lionel A. Stange (Neuroptera), and Arturo Teran (Coleoptera: Bruchidae).

The first phase of the entomological study, which is concerned with making general collections, began in 1968 and is scheduled for 2 years. Ten malaise traps were installed in the first year, and samples are collected at 2-week intervals. Regular collecting and study trips into the area are being made, and a mobile laboratory is used to facilitate studies in remote areas. In the second phase of the study, scheduled for 3 years, more specialized studies will be made. Studies already under way are concerned with bee pollinators of biogeographically or ecologically important plants; insects associated with *Larrea*; seed-feeding insects, especially Bruchid beetles; and sand dune communities, especially the Myreloontidae.

Mediterranean Scrub

Detailed plans were made for work on the convergence of this system, as represented in California and Chile. Research will begin as soon as funds become available.

EVOLUTIONARY AND ECOLOGICAL DIVERSITY

Preliminary efforts have been toward understanding the evolutionary relations of the huge tree frog family Hylidae. The scope of this subprogram has been enlarged to include New World anurans, although the families Hylidae and Leptodactylidae will receive high priority.

Several field expeditions have been made. James P. Bogart, postdoctoral investigator, spent the rainy season of 1967-1968 in the upper Amazon Basin of Peru collecting karyotype material, making hybridization and ecological studies, and recording mating calls. He collected similar material in Colombia in November 1968, and in Argentina and Brazil from September to December 1969. In Brazil he obtained karyotype material for 75 species representing 26 genera and 7 families of anurans.

Several undescribed species were collected in the course of the Peruvian work. One ancillary accomplishment was to ascertain that two species of *Bufo* have been confused under the name *B. marinus*. Both exist sympatrically at Iparia. *B. poeppigi* is relatively small and slender and has narrow parotid glands; *B. marinus* is large and robust and has large parotid glands. These species differ karyologically, in mating call, and in crossability with other species of *Bufo*.

M. J. Fouquette collected *Hyla* and recorded mating calls in Colombia and Venezuela from November to December 1967 and in Panama and Colombia during the summer of 1969. Papers in preparation as a result of this work include: "Mating Calls of Colombian Frogs," by M. J. Fouquette, William F. Pyburn, and V. H. Hutchison; "Review of the Frogs Related to *Hyla boulengeri*," "The Identity of *Hyla rubra* and Related Species," "Brief Note on *Hyla rufitela*," "Breeding Calls of Frogs in Guyana and Surinam," and "*Hyla microcephala* and Related Frogs in Northern South America," by M. J. Fouquette; and "Morphology and Evolutionary Trends in Anuran Spermatozoa," by A. James Delahoussaye.

William F. Pyburn and a student assistant spent June and July in eastern Colombia recording mating calls and collecting stocks of Hylidae. Richard Newcomer, postdoctoral investigator, spent 2 months in the Choco province of northeastern Colombia in late 1968 and 3 months in the llanos of eastern Colombia in early 1969 collecting mating calls and experimental stocks of Hylidae. He returned to Colombia in September 1969 to help establish a biochemical laboratory for the amphibian work at Universidad Javeriana, Bogotá, where Jaime George is cooperating in the project.

Luis Dino Vizotto, University São José do Rio Prêto, Brazil, spent 2 months at the University of Texas in early 1969 to learn techniques of biochemical studies, karyological studies, and hybridization.

In October 1969, William F. Martin, Ford Foundation postdoctoral fellow, went to Medellín, Colombia, where he is establishing a bioacoustical center for the amphibian research.

W. Frank Blair collected experimental stocks of amphibians in Colombia and Argentina in January 1969, and in early February he collected with Alberto Veloso of Valparaiso and Klaus Busse of Santiago in southern Chile. All six species of the leptodactylid frogs of the genus *Eupsophus* were collected along with representa-

*See Appendix A (p. 50).

tives of various other taxa. Subsequent analysis of the *Eupsophus* karyotypes by James Bogart revealed unexpected variability: four different chromosome numbers.

ISLAND ECOSYSTEM STABILITY AND EVOLUTION

Intensive Study of Selected Ecosystems

A comprehensive ecological survey was begun in a 200-acre site occupied by a native montane forest ecosystem. The principal structural components are scattered, tall, big-diameter *Acacia koa* trees and groups of *Metrosideros polymorpha* with several other native tree species as subcanopy members. A third major biomass stratum is formed by tree ferns (*Cibotium* spp.).

The base lines were surveyed and two 1,000-m-long transects were flagged out with 10 plot points at intervals of 200 m. The first sample plot has been completed. In addition to the plant ecological survey, insect and bird surveys are carried out along the same transects. Malaise traps and attractant logs have been placed at various strategic positions in this forest.

A climatic station was installed in August 1970 for continuous recording of temperature and humidity. Rainfall in an open area and under trees is checked at weekly intervals. Precipitation measurements under the canopy are particularly important here, because of the suspected high moisture contribution from cloud interception.

Checklists of all biota in this forest have been prepared, and further sampling techniques are being worked out.

Ecosystem Transect Study

Six ecosystem transects have been defined and described on the island of Hawaii. These range from 10 to 22 miles in length. One extends from the top of Mauna Kea (elevation about 14,000 ft) to the sugarcane fields above Hilo. Another lies parallel to the Mauna Kea transect on the east flank of Mauna Loa, where it traverses similar climates but much younger substrates. The four remaining transects are in Hawaii Volcanoes National Park and extend to the Mauna Loa transect down to sea level.

Each of the 30 principal ecosystems along these transects has been studied in two 500-m^2-plots. The plot locations are being transferred to a new vegetation map having a scale of 1:24,000. Field work for the map has been completed. Sixty-two plant checklists containing quantitative information on species cover are programmed for computer storage and retrieval. Various summaries of this information will be available for any project participant. The same procedure will be followed for checklists of insects and other biota. Seven phenological and two climatic stations were established in different macroclimates along the transects.

Evolution Studies on Endemic Populations

Most of this work has been done along the transects, but some highly specialized populations, such as the Hawaiian Diptera and certain Hawaiian birds, have been studied in different areas. The same is true for the genecological studies of the widely distributed polymorphic tree *Metrosideros*. The evolutionary objectives are pursued on all major islands, particularly on Hawaii, Maui, and Kauai. They are not necessarily tied to the transects.

The ecological studies will be extended eventually to Maui and Kauai.

APPENDIX A: PUBLICATIONS

Auffenberg, W., and W. G. Weaver, Jr. 1969. *Gopherus berlanderi* in Southeastern Texas. Bull. Florida State Museum 13. 3 p.

Blair, W. F. 1969. Especiación en los sapos (genero *Bufo*). Acta Zool. Lilloana XXIV, p. 317.

Blair, W. F. 1970. The influence of the Amazon River Basin on the evolution of toads of the genus *Bufo* of South America. II Simposio y Foro de Biologia Tropical Amazonica: 168-171.

Fouquette, M. J., Jr. 1968. Some frogs from the Venezuelan llanos, and the status of *Hyla misera* Werner. Herpetologica 24:321-325.

Hunziker, J. H., R. A. Palacios, and A. Soriano. 1969. Hibridacion Natural en especies sud americanas de *Larrea* (Zygophyllaceae). Kurtziana 5:55-56.

Solbrig, O. T., C. Passani, and R. Glass. 1968. Artificial hybridization between different polyploid levels in *Glandularia* (Verbenaceae). Amer. J. Bot. 55:1235-1239.

Vuilleumier, B. S. 1969. Evolution and systematics of *Perezia* sect. *Perezia* (Compositae-Mutisieae). Contr. Gray Herb. 199.

APPENDIX B: PARTICIPANTS*

W. Frank Blair, Department of Zoology, University of Texas, Austin (Program Director; SE, niches and microcommunities; EED, anuran work)

Homer Aschman, Department of Geography, University of California, Riverside (SE, land use)

Peter D. Ashlock, Department of Entomology, Bernice P. Bishop Museum, Honolulu, Hawaii (IESE, phytophagous insects, Heteroptera)

Geoffrey C. Ashton, Department of Genetics, University of Hawaii, Honolulu (IESE, genetic analysis of populations)

Franceso J. Ayala, Rockefeller University, New York, N.Y. (EED, Drosophila)

Gladys E. Baker, Department of Botany, University of Hawaii, Honolulu (IESE, ecological roles of the fungi)

Michael G. Barbour, Department of Botany, University of California, Davis (SE, vegetational structure)

John W. Beardsley, Department of Entomology, University of Hawaii, Honolulu (IESE, the effects of sap-sucking Homoptera on the stability and fragility of Hawaiian ecosystems)

*The abbreviations SE, IESE, and EED refer to subprograms. SE = structure of ecosystems; IESE = island ecosystem stability and evolution; EED = evolutionary and ecological diversity.

Andrew J. Berger, Department of Zoology, University of Hawaii, Honolulu (Co-Director, IESE; life history and functional anatomical studies of the Hawaiian honeycreepers)
William S. Birkhead, Department of Zoology, University of Texas, Austin (SE, fish niches)
James P. Bogart, Department of Zoology, University of Texas, Austin (EED, anuran work)
Jerry Boggs, Department of Zoology, San Diego State College, San Diego, Calif. (SE, mammal niches)
Charles D. Bonham, Department of Watershed Management, University of Arizona, Tucson (SE, vegetational structure)
D. E. Bradbury, Department of Geography, University of California, Los Angeles (SE, geomorphology)
Nadir Brum-Zorilla, Instituto de Biologia, Montevideo, Uruguay (EED, anuran work)
Klaus Busse, Centro de Investigaciones Zoologicas, Santiago, Chile (EED, anuran work)
Martin Cody, Department of Zoology, University of California, Los Angeles (SE, bird niches)
Carolyn Corn, Department of Zoology, University of Hawaii, Honolulu (IESE, studies of Metrosideeros)
Chicita Culberson, Department of Botany, Duke University, Durham, N.C. (SE, lichen ecology)
William Culberson, Department of Botany, Duke University, Durham, N.C. (SE, lichen ecology)
Clifton J. Davis, Chief Entomologist, Hawaii Department of Agriculture, Honolulu (IESE, Hawaiian Cerambycid beetles and certain other wood borers)
A. James Delahoussaye, Department of Zoology, Arizona State University, Tempe (EED, anuran work)
Mercedes D. Delfinado, Department of Entomology, University of Hawaii, Honolulu (IESE, biosystematics of Hawaiian Diptera)
Hernando de Macedo, Universidad Cayetano, Lima, Peru (EED, anuran work)
Reinaldo Diaz, Department of Zoology, University of Texas, Austin (EED, anuran work)
Francesco di Castri, Instituto de Ecologia, Universidad Austral de Chile, Valdivia (Co-Director, Mediterranean Scrub Project, SE; soil community structure)
Theodosius Dobzhansky, Department of Zoology, Rockefeller University, New York, N.Y. (EED, Drosophila work)
Maxwell S. Doty, Department of Botany, University of Hawaii, Honolulu (IESE, ecological and evolutionary roles of the algae)
Lee Ehrman, Department of Population Genetics, Rockefeller University, New York, N.Y. (EED, Drosophila work)
M. J. Fouquette, Department of Biology, Arizona State University, Tempe (EED, anuran work)
Wayne C. Gagne, Bernice P. Bishop Museum, Honolulu, Hawaii (IESE, phytophagous insects, Heteroptera)
Jaime George, Universidad Javeriana, Bogotá, Colombia (EED, anuran work)
Roger D. Goos, Department of Botany, University of Hawaii, Honolulu (IESE, ecological roles of the fungi)
J. Linsley Gressitt, Department of Entomology, Bernice P. Bishop Museum, Honolulu, Hawaii (Co-Director, IESE; Hawaiian Cerambycid beetles and certain other wood borers)
Sheldon Guttman, Miami University, Oxford, Ohio (Co-Director, EED; anuran work)
Ernst R. Hajek, Department of Ecology, Universidad Catolica de Chile, Santiago (SE, microclimate)
Frank H. Haramoto, Department of Entomology, University of Hawaii, Honolulu (IESE, behavior and population dynamics of endemic insects)
D. Elmo Hardy, Department of Entomology, University of Hawaii, Honolulu (IESE, evolution and genetics of Hawaiian Drosophilidae, biosystematics of Hawaiian Diptera)
Fabio Heredia, Universidad de Antioquia, Medellín, Colombia (EED, anuran work)
Jorge Hernandez, Instituto de Ciencias Naturales, Bogóta, Colombia (EED, anuran work)
Don Hunsaker, Department of Zoology, San Diego State College, San Diego, Calif. (SE, mammal niches)
Juan H. Hunziker, Department of Genetics, University of Buenos Aires, Argentina (SE, *larrea* and *prosopis* genetics and biochemistry)
Jaime Hurtubia, Instituto de Ecologia, Universidad Austral de Chile, Valdivia (SE, leaf insect niches)
Albert W. Johnson, Dean of Sciences, San Diego State College, San Diego, Calif. (SE, plant species diversity)
John M. Kingsolver, Agricultural Research Service, U.S. Department of Agriculture, Washington, D.C. (SE, arthropod niches)
John Kirsch, Department of Zoology, University of Kansas, Lawrence (SE, marsupial convergence)
Charles H. Lamoureux, Department of Botany, University of Hawaii, Honolulu (IESE, growth rates and anatomy of woody plants in relation to environment)
Robert M. Lloyd, Department of Botany, University of Hawaii, Honolulu (IESE, life history studies of ferns)
Charles H. Lowe, Department of Zoology, University of Arizona, Tucson (SE, vegetational structure)
Bertha Lutz, Museu Nacional, Rio de Janeiro, Brazil (EED, anuran work)
Tom J. Mabry, Department of Botany, University of Texas, Austin (SE, plant biochemistry)
Michael A. Mares, Department of Biology, University of Texas, Austin (SE, rodent niches)
William F. Martin, Universidad de Antioquia, Medellín, Colombia (EED, anuran work)
Terry Matthews, Department of Zoology, University of Texas, Austin (SE, amphibians)
Ming-Pi Mi, Department of Genetics, University of Hawaii, Honolulu (IESE, computerization)
Phillip C. Miller, Department of Biology, San Diego State College, San Diego, Calif. (SE, microclimate)
Wallace C. Mitchell, Department of Agriculture, University of Hawaii, Honolulu (IESE, biology-ecology and control of insects attacking the silverswords in Hawaii)
Andrew R. Moldenke, Department of Biology, Stanford University, Stanford, Calif. (SE, pollination systems)
Harold Mooney, Department of Biological Sciences, Stanford University, Stanford, Calif. (Co-Director, Mediterranean Scrub Project, SE; vegetational structure)
Jorge Morello, Instituto Nacional de Tecnologia Agropecuaria, Buenos Aires, Argentina (Co-Director, Desert Scrub Project, SE; vegetational structure)
Dieter Mueller-Dombois, Department of Botany, University of Hawaii, Honolulu (Co-Director, IESE; vegetation-environment correlation studies, studies of distributional dynamics, life history studies of important plants: angiosperms)
Craig E. Nelson, Department of Zoology, Indiana University, Bloomington (Co-Director, EED; anuran work)
Richard Newcomer, Department of Biology, University of Texas, Austin (EED, anuran work)
Toshiyuki Nishida, Department of Entomology, University of Hawaii, Honolulu (IESE, behavior and population dynamics of endemic insects)
Dan Otte, Department of Zoology, University of Texas, Austin (SE, arthropod niches)
William F. Pyburn, Department of Biology, University of Texas, Arlington (EED, anuran work)
Frank J. Radovsky, Acarologist, Bernice P. Bishop Museum, Honolulu, Hawaii (IESE, parasites of vertebrate animals of Hawaii)
Dennis Ralin, Department of Zoology, University of Texas, Austin (EED, anuran work)
Peter Raven, Department of Biology, Stanford University, Stanford, Calif. (SE, pollination systems)
Juan Rivero, University of Puerto Rico, Mayaguez (EED, anuran work)
Herbert H. Ross, Entomology Department, University of Georgia, Athens (SE, arthropod niches)

Pedro M. Ruiz-C., Universidad Nacional de Colombia, Bogotá, Colombia (EED, anuran work)
Francisco Alberto Saez, Instituto de Biologia, Montevideo, Uruguay (EED, anuran work)
Richard D. Sage, Department of Zoology, University of Texas, Austin (SE, lizard niches)
Francisco Saiz, Department of Entomology, Universidad Austral de Chile, Valdivia (SE, beetle niches)
G. Allen Samuelson, Department of Entomology, Bernice P. Bishop Museum, Honolulu, Hawaii (IESE, Hawaiian Cerambycid beetles)
Eduardo Sanchez, Universidad Nacional de Chile, Santiago (SE, plant biochemistry)
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Richard B. Selander, Department of Entomology, University of Illinois, Urbana (SE, arthropod niches)
Jean-Pierre Simon, Department of Botany, Claremont Graduate School, Claremont, Calif. (SE, plant biochemistry)
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Arturo Teran, Department of Zoology, Instituto Miguel Lillo, San Miguel de Tucuman, Argentina (SE, insects)
Wallace B. Thompson, Department of Biology, University of Texas, Austin (SE, plant biochemistry)
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HUMAN ADAPTABILITY COMPONENT

Population Genetics of South American Indians

Human adaptability has two components: the genetic, which sets the limit of the organism's ability to respond, and the physiological, which determines the range of response available to the organism within the genetic limit.

With the development and ascendancy of agriculture some 10,000 years ago in the Old World, and even more recently in the New, one of man's most successful social forms, the tribe, was transformed successively into the city, the state, and, ultimately, the nation. Dramatic changes also took place in the realm of technology and demography, increasing both man's need and his ability to penetrate new ecological zones on an unprecedented scale. These dramatic changes took place within the last 1 percent of human cultural and biological evolution. One of the consequences is that the present major populations of the world owe their numerical and biological significance to very recent events.

In his long career as a tribesman, man adapted, both culturally and physically, to a wide range of climates and geographical conditions. The Age of Discovery, barely a few centuries behind us, found tribal cultures successfully and intimately adapted to boreal and tropical forests, tundra, deserts at high and low altitudes, grasslands, the arctic, and insular, riparian, and riverine ecological zones. Wherever such cultures were found, they exhibited a remarkable variability in specific technological adjustments required by particular environments. Socially and demographically there was, however, a remarkable degree of similarity among tribesmen.

The recent and continuously accelerating spread of civilized culture has replaced or transformed many of the adaptations that are known to have existed, but there still remain a number of very significant tribal populations in various parts of the world. Some of these can be taken to approximate the social, demographic, epidemiological, and ecological circumstances under which man evolved for the greater part of his history.

Because of man's long history as a tribesman and the surprisingly narrow range of social types exhibited among tribesmen, the study of these remaining unacculturated tribes will provide a critical base line for our understanding of human adaptability to a wider, more complex range of social and technological circumstances.

Man's genetic diversity and most of his adaptations arose while he was living at the tribal level of culture, as a hunter and gatherer or as a neolithic farmer. There are many insights into the population genetics of civilized man that can be gained only from studies on such primitive populations. The term "primitive" as here used means a population socially and politically organized along lines of kinship, the hallmark of tribal society. Actually, many aspects of "primitive" society are breathtaking in their sophistication and complexity. The resilience and durability of many aspects of tribal social organization are evidenced in the many rural, peasant populations of the world today.

This program is directed by James V. Neel, Chairman, Department of Human Genetics, University of Michigan Medical School, Ann Arbor.

OBJECTIVES

This program seeks to answer four basic questions of scientific interest:

- What is the tempo of human evolution as measured by the degree of divergence that has arisen between Indian groups since their arrival in the Americas?
- For such Indian groups as still exist in a pre-Columbian state, what significant biological parameters affected their evolution?
- What patterns of social and biological adaptation emerge as primitive Indian groups are subjected to cultural change?
- To what extent do cultural and social practices (marriage, settlement pattern, intergroup hostility) affect the biological and demographic characteristics of the population?

RESEARCH METHODS AND PROGRESS

To obtain the basic data necessary to answer these questions, specialists from several disciplines participate in both the actual field studies and the laboratory analyses of the biological specimens. These disciplines include social anthropology, physical anthropology, linguistics, medicine, genetics, serology, and chemistry. Our participants in Latin America include members of the Venezuelan IBP and the Brazilian IBP.

The principal efforts of this program are directed toward the Yanomama Indians of Venezuela and Brazil. Less extensive studies have been performed on the Xavante of Brazil and the Makiritare of Venezuela and Brazil. The Yanomama speak only their native language, an American Indian tongue that is thus far not demonstrably related to any of the well-described linguistic groupings of South America. Accordingly, it was necessary from the outset to develop the anthropological and linguistic groundwork on which the feasibility of many of the related studies depended. The cultural anthropologist spent 15 months with the tribe prior to the initiation of the medical and genetics work. During this time he acquired a proficiency in the language and established rapport and contact with the villages that were later selected for study. Genealogical and demographic data and information on recent village histories and interrelationships were also collected during this phase of the work.

Subsequent to this, five expeditions have been made to the Yanomama tribe, in the course of which 40 villages were contacted and investigated. A few of these villages were contacted by non-Indians for the first time in their history when visited by members of our group, attesting to both the relative cultural purity of the tribe and the remoteness of the villages. To date our information includes (1) the most extensive demographic and settlement pattern data available for any primitive group at this cultural level, (2) typing of some 2,565 blood and saliva specimens for 28 genetic systems, (3) some 655 physical examinations, (4) anthropometric measurements on 402 persons, (5) dental studies on 473, and (6) dermatoglyphics on 488.

These data have resulted in a number of specific analyses and publications. The high points of some of the initial results follow.

Extensive studies on serum antibodies have been performed by the Communicable Disease Center of the U.S. Public Health Service and by collaborators at the Venezuelan Institute of Scientific Investigations. In the course of three expeditions, extensive genealogical data and blood and saliva typings have been made on 594 Makiritare Indians from 7 villages. Gene flow between these two tribes has taken place and new genes have entered the Yanomama population at the tribal interface, often a consequence of the fact that the Yanomama periodically raid the Makiritare and abduct women from them. In one instance a unique and previously unreported gene (a serum albumin gene) was discovered in a Yanomama village in an abducted Makiritare tribeswoman and her progeny, she being the only survivor of her tribe. The others were exterminated by the Yanomama (Weitkamp and Chagnon, 1968; Chagnon *et al.*, 1970).

We have taken some 30,000 ft of film on the Yanomama. This has been obtained both as a research resource and for preparing several teaching films. The teaching films are needed because of the difficulty experienced in describing the nature of the Yanomama to a student or scientific audience. One ethnographic film, "The Feast," has already been prepared.* It depicts a central social and political function in the political life of the Yanomama. Two films are in preparation.

GENERAL HEALTH AND REPRODUCTION

The general health of the Xavante and Yanomama has been assayed by vital statistics and by physical examinations on an unselected cross section. The vital statistics on the Xavante have been summarized (Salzano *et al.*, 1967). The more extensive material on the Yanomama has been published in preliminary form (Neel and Chagnon, 1968). An accurate demographic characterization of all aspects of the Yanomama population is very difficult to obtain. These data must be collected from people whose culture places a value on recall of deceased children that differs greatly from that of our culture. In the case of the Yanomama, the culture actually discourages mention of deceased children, so that information is collected through informants other than the mother or father. While it is possible to collect accurate data that clearly show the genealogical relationships among widely separated villages, it is difficult to estimate such basic demographic parameters as completed family size. Nevertheless, our data, which probably underestimate the population, clearly indicate that the population is growing. In addition, village histories and settlement data indicate that it is also expanding geographically (Chagnon, 1968a; 1968b; Neel and Chagnon, 1968).

By the time Xavante women have completed their reproductive performance by virtue of age or death, 33 percent of their children have already died prior to the age of reproduction; the corresponding figure for the Yanomama is 16 percent. These figures exclude infanticide. The higher death rate among Xavante is attributed to the fact that measles and pertussis have swept through them in the past decade (Salzano *et al.*, 1967), whereas at the

*This 16-mm film was prepared by T. Asch and N. A. Chagnon in 1970. It is distributed by the National Audiovisual Center, National Archives and Records Services, Washington, D.C. 20409.

time the statistics were collected, the Yanomama were still "virgin" for these two diseases (Neel *et al.*, 1970).

In the case of the Yanomama, the pregnancy rates implied by vital statistics were checked through two independent approaches: (1) abdominal palpation of as many women as possible who are estimated to be in the reproductive age, and (2) determination of urinary chorionic gonadotrophins on these same women. In a group as unacculturated as the Yanomama, each of these efforts presents a few problems. If we assume a Yanomama woman to be exposed to the risk of pregnancy from age 15 to 40, the reproductive histories suggest a child every 6 or 7 years on the average. Physical examinations of 214 Yanomama women suggest a birth every 2.8 years, and urine studies, one every 3.8 years (Neel and Chagnon, 1968). Some of this discrepancy is almost surely due to underreporting; the remainder may be more apparent than real. The Yanomama practice abortion, at a relatively late stage of gestation, as well as infanticide—the latter immediately following delivery. An abortion or infanticide is rarely reported in a reproductive history, but these pregnancies would be detected by the supplementary approaches to the question.

One significant aspect of Yanomama infanticide is that more female children are killed at birth than male children. In some areas of the tribe, one third of the adult males die in warfare. Here, a high value is placed on male children who grow up to be warriors. Accordingly, disproportionately more females are destroyed at birth. Villages in these areas have a tertiary sex ratio of 1.40 compared with 1.20 for villages at the less warlike tribal periphery (Chagnon, 1968a).

Figure 1 presents the Yanomama life-expectancy curve. This curve represents natural causes of death only; it excludes infanticides. It is almost certain to be modified as recently collected demographic data are incorporated. For contrast, we present the curve of a tropical agricultural population (India in 1901–1911, before the full impact of modern health measures had been felt) and the curve of a highly civilized, well-industrialized country (Japan in 1960). Incidentally, there is almost surely gross underreporting of infant mortality in the data from India. There are two important points to be made from these data:

- Primitive populations were probably not of the so-called high-fertility, high-mortality type. This has great significance for our thinking concerning the circumstances under which the genetic polymorphisms came into being and were maintained (i.e., the mortality base of natural selection).
- These findings indicate the possible role of reproductive compensation in maintaining genetic polymorphisms. Evidence has been developed for the occurrence of reproductive compensation in consanguineous marriages in Japan. As long as primitive man is thought of as

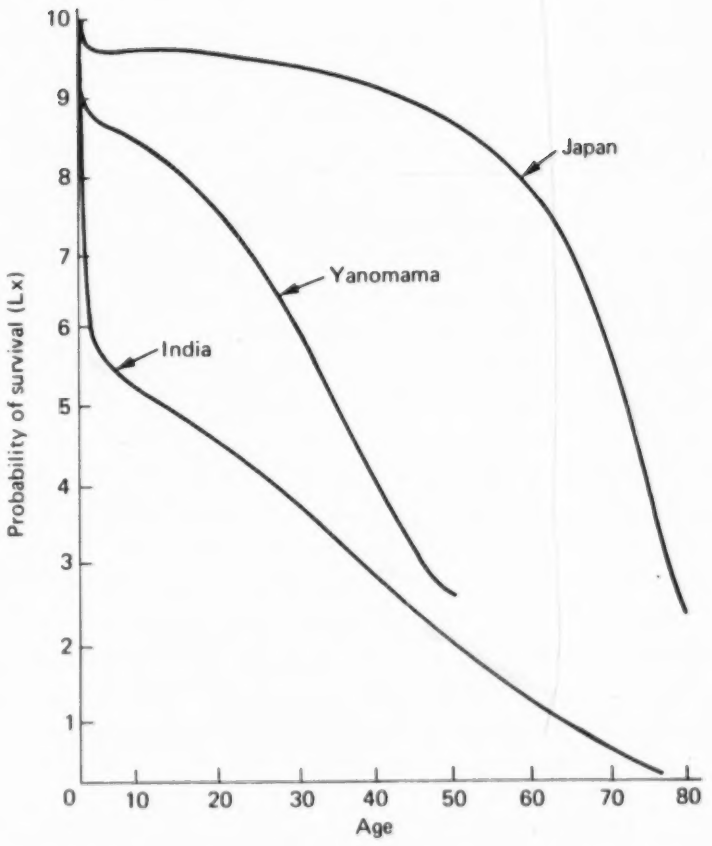

FIGURE 1 Life-expectancy curves for a primitive culture (the Yanomama), an advanced agriculturally based culture in the tropics (India in 1901–1911), and an industrialized culture (Japan in 1960). Deaths due to infanticide have not been included in the Yanomama curve. All three curves are for males only.

reproducing at near capacity in order to maintain his numbers, there is little reason to consider reproductive compensation. But with the opportunities for compensation that exist in the demographic pattern just described, it is obvious that the role of compensation must be explored.

The findings on physical examination (Neel *et al.*, 1964; Weinstein *et al.*, 1967) indicate that, by the usual standards, the Xavante and Yanomama are healthy people. In view of the fact that these groups kill malformed infants at birth, the number of persons observed to have major congenital defects was surprising. Among a total of 287 Xavantes who were examined, there were 7 congenitally defective (3 severely mentally defective, 1 with club feet, 1 with polydactyly, and 2 with signs of congenital heart disease). Among the first 274 Yanomama examined, we have observed 7 cases of congenital defect (6 with signs of congenital heart disease, 1 achondroplastic dwarf). The diagnoses of congenital heart disease are based on auscultation. Since most children with serious or obvious defects die through infanticide or natural causes, a relatively high proportion of defective children is indicated.

The relatively good health and nutrition of the children is especially noteworthy. The high gamma globulin

levels of the mothers (cf. Neel *et al.*, 1964, 1968a) imply a considerable passive transfer of immunity, and the prolonged period of child nursing, about 3 years, not only provides for some possible additional transfer of maternal antibodies, with a relatively smooth transition from passive to active immunity, but also gives the child a fine nutritional base (discussion in Neel *et al.*, 1964; Neel and Salzano, 1967).

In view of this picture of health among the children and young adults, the small number of older persons is an enigma. The mean age in the villages of these Indians is about 20 years; only 19.2 percent of the population were thought to be over 30 years of age. Studies on serum antibodies suggest early acquisition of immunity to most of the local infectious diseases (Neel *et al.*, 1968b); hence, one would expect most of the adults to acquire immunity to the endemic diseases. Recent epidemics of measles and pertussis among the Xavante may have killed a disproportionate number of old people, and falciparum malaria, which may only now be reaching certain Yanomama villages, may have had a similar effect. Nutritional disease seems unlikely. Records of the two anthropological associates contain numerous accounts of traumatic death, through warfare or following accusations of sorcery.

MICRODIFFERENTIATION

The genetic distances between seven randomly chosen Yanomama villages and seven Makiritare villages were calculated from data on eight gene frequencies by using the distance function developed by Cavalli-Sforza and Edwards. The mean distance between the Yanomama villages is 0.330 units, and between the Makiritare villages, 0.356 units. The mean distance for the same eight gene frequencies between 12 Indian tribes of Central and South America is 0.385 units. Thus, the average distance between Indian villages is 85.5 to 92.4 percent of the distance between tribes. In both of these tribes, the degree of genetic differentiation from one village to the next is felt to be noteworthy. These genetic differences are attributed to the fact that a new Indian village usually results from the fissioning of an established village. This fissioning is structured by factors of kinship and tribal marriage practices, so that division of the village (and tribal) gene pool at the time of a split is highly nonrandom. Moreover, the political relationships of the groups that result from the fissioning of a village are usually hostile, and the groups tend to resettle a considerable distance from each other. Thus, political forces and warfare lead to a settlement movement that has a centripetal motion. The movement enhances the possibility that initial genetic differences in recently related populations will be maintained as populations migrate away from one another.

POLYGYNY AND THE GENETIC SIGNIFICANCE OF DIFFERENTIAL FERTILITY

The Xavante, Yanomama, and Makiritare are polygynous. In these cultures one reward for male achievement and longevity is additional wives. This appears to be the pattern in many primitive cultures. Women appear committed to a pattern of child-spacing, which in Yanomama women, living to age 40, results in a low variance in number of reported live births. The mores of these primitive societies tend to minimize the variance in number of live births per female but maximize the variance in number of children per male.

It has proved quite difficult to obtain the kind of hard data that can be employed in population simulation models designed to quantify the genetic consequences of polygyny.

During the past 2 years, attempts have been made to develop a computer model that simulates the genetic and demographic structure of the Yanomama. The basic input is detailed demographic data from four villages. One of the objectives of this simulation is to derive an estimate of the amount of inbreeding. There were great difficulties in reconciling certain aspects of the inbreeding results, after 150 simulated years, with the results of the first 20 simulated years even though in many other respects there was a good accord with the facts. During the first 20 simulated years, the real population dominated the findings. On the average, during the first 20 simulated years, the members of the real population were more closely related to one another than were the members of the simulated population at 150 years. Even when the model specified the maximum opportunity for consanguineous marriages consistent with field data, the predicted level of inbreeding declined with time.

The reason became clear when the distribution of the number of grandchildren per male was considered. A disproporti nate number of grandchildren are born to a few males, a situation that greatly increases the possibilities of full or half first-cousin marriage. Genetic significance is added to this phenomenon by the fact that the four males whose living grandchildren outnumber those of any male in the computer population represent two father-son combinations. One reason for this "familial" fertility seems to be that if, because of the polygyny of his father, a young man possesses many sisters or half-sisters (who can be "traded"), that young man has an advantage in forming alliances and obtaining extra wives, so that polygyny begets polygyny. The phenomenon does not appear to be primarily genetic; rather, it reflects some of the systematic marriage and alliance formations characteristic of tribal cultures in general and the Yanomama in particular. One of the discoveries resulting from the interplay of the computer-simulation attempts and

the demographic and cultural parameters defined by the anthropologist is the surprisingly large amount of inbreeding that takes place in populations such as this. Whereas a mean coefficient of relatedness of F=0.02 is generally accepted as a limit for most human populations, actual data and simulations based on them show that this value may be greatly exceeded (MacCluer *et al.*, in press).

The degree of differential fertility must be another factor in the marked genetic microdifferentiation between villages. The number of wives a man obtains and holds also depends on personal attributes, unquestionably to some extent genetically determined. Here is an example of an interaction between the genetic system and the social system. The field impression is that the polygynous Indians, especially the headmen, tend to be more "intelligent" than the nonpolygynous. They also tend to have more surviving offspring. Polygyny in these tribes thus appears to provide an effective device for certain types of natural selection.

The possible genetic implications of polygyny are clear, but some of the facts necessary to a meaningful treatment are still lacking. Future investigation will attempt to contrast certain mental attributes of polygynous males with those of nonpolygynous males.

RATE OF HUMAN EVOLUTION

All known data on gene frequencies in various tribes of American Indians were tabulated. From these data tribes were chosen for consideration on the basis of meeting the following criteria: (1) sample size greater than 200, (2) non-Indian admixture estimated at less than 5 percent, and (3) data on the six genetic loci named below plus the ABO locus. Since all the unmixed Indians of Central and South America appear to be type 0, the last-named locus is of little value in distance measurements but very important in opinions concerning admixture with non-Indians.

There were 12 tribes located in Central and South America meeting these criteria. The genetic distances between these 12 tribes, and the probable time of arrival of the Indian in Central and South America, have been used to estimate the *maximal* rate of gene substitution in these groups. The estimate was 130,000 years/gene substitution/locus in any one line of descent since the arrival of the Indian in Central and South America. Gene substitution was defined in terms of the additive components of the vector space utilized to find the genetic distances between populations. The estimate is based on cumulative change at only six genetic loci (the MNSs, Rh, Kidd, Dufy, Diego, and haptoglobin loci). Among the assumptions in this approach are (1) that changes in diverse directions at various loci can be equated to directional change at one locus, and (2) that the coefficient of selection is about the same at all gene frequencies—frequency-dependent selection is relatively unimportant.

MEASLES

Immunological studies on sera collected during the 1966 expedition revealed the Yanomama to be a "virgin" population with regard to measles. Measles was introduced into the Yanomama from Brazil just at the time of the arrival of our 1968 expedition. There resulted a most unusual opportunity to document (and be involved in) the course of an epidemic in such a group. Observations suggest that the bulk of the morbidity and mortality in such populations may be ascribed to the epidemiology of the disease under these circumstances. When all the population is ill there is a complete collapse of village life. There is no one to gather food or bring water. Febrile individuals dehydrate rapidly in the tropics, especially nursing infants whose mothers have measles. An additional factor is the fatalistic attitude of the Indian toward such epidemics. He tends to lie quietly doubled up in his hammock awaiting death (excellent for bronchopneumonia).

ESCHERICHIA COLI STUDIES

Studies have been undertaken with various collaborators, at the Venezuelan Institute of Scientific Investigations, the U.S. Communicable Disease Center, and the University of Michigan on the antibodies to pathogens detectable in serum specimens. Antibodies to Salmonella and Shigella antigens were encountered rather frequently. However, diarrhea seemed a less common cause of morbidity and mortality than in many agricultural populations. In order to investigate this matter, in 1967, 72 stool specimens were transported to Ann Arbor for culture by Dr. Warren Eveland. There were no Salmonella isolations. Attention thus turned to the *Escherichia coli*, and 6 strains were isolated from each of these 72 specimens. Attempts were made to type these out with a battery of typing sera as near complete as could be assembled. This battery would type about 99 percent of *E. coli* isolated in the United States. However, only 50 percent of these *E. coli* have typed out. Antisera against some of the untypable strains have been developed. At this point at least six previously undescribed strains are recognized. Within the past year, stool specimens from Cali, Colombia, and Caracas, Venezuela, have been brought back for the isolation and typing of additional *E. coli* strains. The additional samples were collected to determine whether these new strains are widespread in South America or characteristic of Indian populations. The pathogenicity of these strains is still undetermined.

The epidemiology of primitive man may differ from that of civilized man, and there is a possibility of marked local differentiation in bacterial pressures.

CHROMOSOME ABNORMALITIES

In the course of the 1969 field work, a study of the frequency of chromosomal abnormalities was performed in three Yanomama villages and one Piaroa village. The objective was to obtain a base line for chromosomal damage in a population essentially unexposed to radiation, pesticides, and the like. Heparinized blood samples obtained in villages near airstrips were refrigerated and flown to a temporary cytogenetics laboratory established at the Venezuelan Institute for Scientific Investigation. The samples usually arrived within 36 hours of collection. They were cultured, and preparations were made that were read in Ann Arbor. Where possible, 100 cells were scored per individual. Members of the expedition served as controls. An effort was made to assemble an age- and sex-stratified sample of largely unrelated individuals. The amount of damage is clearly greater than was expected. Some cells show striking damage. Present data indicate that highly complex chromosomal aberrations are found in individuals of all ages and of both sexes.

In the future we will extend our collecting of genetic and anthropological data to Yanomama villages that have not been studied.

We will initiate auxiliary studies on the Yanomama, including ethnobotanical studies and dental studies. An ethnobotanist and a zoologist will be added to the field team. The ethnobotanist will explore the botanical resources of the tropical forest culturally significant to the Yanomama. The zoologist will do the same for the protein aspects of Yanomama economic productivity.

We intend to initiate the same kind of multidisciplinary and multinational studies among several other South American tribes. One of these tribes was contacted for the first time late in 1969 and is totally unknown.

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Biology of Human Populations at High Altitudes

Exploring the stresses associated with high altitude is one of the best approaches to determining the limits of human ability to adapt to environmental stresses. A good experimental situation is provided by the fact that at high altitude the stress level produced by hypoxia is extreme. Technological change has not substantially ameliorated the effect of the lower atmospheric pressure. This contrasts with stress such as that produced by climatic extremes in temperature where technology can reduce or even eliminate the stress. Also, the hypoxias related to altitude appear to have significant effects on the manifestations of several degenerative diseases that are of major importance to a large segment of the world population.

Human survival, health, and productivity all appear to be modified significantly by residence at high altitude. The apparent reduction in fertility at high altitude is noteworthy in view of the current population explosion elsewhere. Among populations living in the Andes, blood pressure is lower and fatal heart attacks appear less frequent than in populations at sea level. This suggests that the high altitude environment may afford some protection from degenerative cardiovascular diseases, which are the major causes of death in the United States today. However, a man migrating to high altitude must accept the fact that his work output will be less than if he stays at sea level. These are but a few of the observations that have prompted this study of man's adaptability to the environmental stress of high altitude.

Co-directors of this program are Paul T. Baker, Pennsylvania State University; Robert F. Grover, University of Colorado; and John Rankin, University of Wisconsin. Dr. Baker began studying the Indian populations of the high Andes in 1962 and established a permanent field station in Nuñoa, Peru, at 4,000 m, which has functioned continuously since 1964. Dr. Grover began his studies of the population of Leadville, Colorado, at 3,100 m, in the Rocky Mountains in 1961 and established a permanent laboratory there in 1964. Together with Dr. Rankin, they submitted the pilot description of this program in the spring of 1968 and submitted major proposals later that year. The proposals were a logical extension of well-founded research programs involving the collaboration of investigators from several disciplines in the United States and Peru. Although the major proposals have not been funded, smaller research projects on related topics have progressed without interruption.

OBJECTIVES

The general objective of the program is to obtain an understanding of how human populations at high altitude adapt to their environment and of what happens to their biology when they migrate downward. Since this general objective is too broad for complete exploration during the tenure of the IBP, certain aspects are being emphasized.

- How does residence in the high altitude environment modify the incidence, severity, and natural history of human degenerative cardiovascular diseases (e.g., systemic hypertension, myocardial infarction, pulmonary thromboembolism, and stroke)?
- What is the incidence of maladaptation to high altitude, (e.g., excessive polycythemia, chronic mountain sickness, acute pulmonary edema, central nervous system dysfunction)? How frequently is intolerance to altitude the major factor in the decision to leave the high altitude environment?
- How is reproductive capacity reduced in human populations at high altitude? Are there fewer pregnancies (male or female infertility), more spontaneous abortions, fewer live births? Are there any differences in the incidence of congenital malformation or infant mortality?
- Does altitude modify human growth and development?
- Do native high altitude populations show evidence of better biological adaptation to altitude than upward migrants, and if so at what stage are these adaptations manifest?
- Do downward migrants develop health problems that are specifically related to their previous adaptation to altitude?

RESEARCH PLANS

For several reasons the scientific goals of this program can be achieved only by conducting several carefully coordinated subprograms.

"High altitude" is not a single elevation above sea level, but a continuum. Altitude as a significant physiological stress begins at about 10,000 ft and extends to about 17,000 ft, the upper limit tolerable for permanent human residence.

Human adaptation to high altitude occurs in varying degrees and is often less than complete. Factors involved include altitude itself; a person may adapt completely to 10,000 ft but not to 14,000 ft. Age is important; young people adapt more readily than adults. Women appear to have a better physiological adaptation than men. There is always a spectrum of physiological responses among individuals; this is greatest in people from sea level who move to altitude.

Man's tolerance of a particular high altitude environment depends not only on physiological response to hypoxia but also on a variety of biological and cultural factors. Differences in the diet, social expectations, child-rearing practices, and disease treatment are a few factors that may affect responses to altitude. The factors can be evaluated only by comparing them in several communities.

Because of these factors, interpopulation and intrapopulation comparisons are needed. Data for the comparisons will be gathered in five subprograms:

1. Study of the population of Leadville, Colorado, in the Rocky Mountains. The altitude is 10,000 ft (moderate).

2. Study of two sea-level communities in the United States: Framingham, Massachusetts, and Tecumseh, Michigan. These communities have been under investigation for several years, and considerable information is available.

3. Study of a sea-level community in the Andes–Cocrachra, Peru.

4. Study of a community at moderate altitude in the Andes (not yet selected).

5. Study of a community at high altitude in the Andes–Nuñoa, Peru (13,000 ft).

The subprogram dealing with the population of Leadville, Colorado, will be comprehensive and sophisticated. Knowledge about the capacity for long-term adaptation to altitude among persons of European ancestry is of great importance, since most available data were obtained on Andean Indians. The desired knowledge can be gained at Leadville. The oldest families have been there for four generations. One finds not only natives representing these families but also newcomers of various ages, some of whom have lived at altitude for many years. Since living standards are similar to those in many low-altitude populations in the United States, nonaltitude factors are minimized. This fact simplifies the task of identifying the effects of altitude *per se*. The entire study is made feasible by community acceptance and cooperation.

Data from ongoing research will be used in the subprogram dealing with Framingham and Tecumseh.

A comparison of two communities at the same altitude, one in the United States and one in the Andes (subprograms 1 and 4), will serve to evaluate genetic factors operating through many generations.

Subprograms 3 and 5 will provide maximum contrast between the effects of hypoxia on genetically similar populations, and they will show the effects of downward migration of a population with maximal high-altitude acclimatization.

Subprograms 1, 4, and 5 will provide maximum contrast between the effects of factors other than hypoxia (e.g., diet, race, and physical activity) that may be important in explaining the lower incidence of cardiovascular disease in the Andes.

In each community, a large amount of biomedical and social data will be collected on each member of the population sample. The data will be collected in a form that will be suitable for computer processing. This will permit efficient analysis, cross comparisons, and ultimate synthesis.

RESEARCH METHODS AND PROGRESS

Extensive groundwork has been laid for the proposed studies; persons and organizations skilled in population surveys have been contacted at the University of Wisconsin. Detailed plans for a special census of Leadville have been completed. Only funding is needed to activate these plans.

The base of operations in Leadville is the High Altitude Research Laboratory in St. Vincent's Hospital. This laboratory was established in 1964 by Dr. Grover and has been funded by the National Institutes of Health (NIH) for the past 7 years. Continued support has been requested.

In Nuñoa, Peru, community research is conducted from a research laboratory that Dr. Baker constructed there in 1964. Activities are coordinated in Nuñoa and in Lima by Tulio Velasquez, San Marcos University.

Despite the lack of comprehensive funding, there has been progress in some aspects of the research. The appended list of publications indicates the general nature of results to date. The following paragraphs refer to specific results achieved during 1969.

Working Capacity

The physical working capacity of a group of Leadville natives and comparable groups of sea-level natives was determined at both high and low altitudes. The working capacity of the two groups was identical at sea level and was reduced equally (25 percent) in both groups at altitude. Thus, the Leadville native exhibits no advantage in capacity for physical work at altitude in spite of acclimatization to altitude from birth. (This conclusion is in contrast with the apparent advantage enjoyed by the Andean native.)

Participants: John T. Reeves and Robert F. Grover.

Diffusing Capacity of the Lung

The capacity of the lung to transfer oxygen from air to blood (pulmonary diffusing capacity) was measured in men and women at sea level, in natives of Leadville, and in newcomers adapted to high altitude. Diffusing capacity at high altitude was significantly greater in the natives of Leadville but not in the newcomers, implying that lung structure is augmented by development at high altitude.

Participants: Robert L. Johnson, Arthur C. DeGraff, John M. Miller, and Robert F. Grover.

Performance of the Heart

The quantity of blood pumped by the heart per beat (stroke volume) and per minute (cardiac output) was measured in Leadville residents and in comparable sea-level residents at both high and low altitudes. Both stroke volume and cardiac output are reduced at high altitude both in newcomers and in adapted long-term residents. This is probably the major factor causing the reduction in working capacity at altitude. (These findings are in contrast with data from Andean natives, whose cardiac output at altitude is not reduced.)

Participants: Loren H. Hartley, James K. Alexander, and Robert F. Grover.

Coronary Circulation

Because cardiac output is reduced at high altitude, while blood pressure remains unchanged, the work of the heart is reduced. Thus, the heart muscle requires less oxygen, and the demands on the coronary circulation are less (coronary blood flow is reduced at high altitude). These findings have potentially beneficial implications for persons with coronary artery disease.

Participants: James K. Alexander, Roberto Lufsharowski, and Robert F. Grover.

Effect of Cigarette Smoking

Cigarette smoking not only reduces the capacity of the blood to carry oxygen (carboxy hemoglobin); it also reduces the oxygen pressure in the blood. When the oxygen pressure is already lowered at high altitude, the further reduction caused by smoking becomes very significant. At high altitude (Leadville), an excessive thickening of the blood (polycythemia) sometimes results. If the affected persons stop smoking, the polycythemia disappears in 3 months. Thus, in some persons, an apparent maladaptation to high altitude (polycythemia) may be caused by cigarette smoking.

Participants: George J. Brewer, John Eaton, John V. Weil, and Robert F. Grover.

Fertility and Neonatal Mortality

Demographic data from a high-altitude Peruvian population suggest that extreme altitude may have a slightly depressant effect on fertility and certainly affects neonatal mortality. Analysis on the project is continuing.

Participants: Paul T. Baker and James S. Dutt.

Effects on Growth

The study of the effects of altitude on the growth of high-altitude natives in Peru suggests that the rates of growth may be slowed at extreme altitudes. However, the study of downward Indian migrants indicates that the unusually large chest characteristic of high-altitude natives may be genetically fixed. Second-generation natives at low altitude had adult chest measurements comparable with those of genetically similar natives at altitude. Study of this problem, including the relationship between chest measurements and lung function, is continuing.

Participants: A. Roberto Frisancho, Charles J. Hoff, and Paul T. Baker.

Responses to Cold

A series of studies of responses to cold have been completed. These studies indicate that the high-altitude native has unusually high peripheral blood flow in the presence of exposure to cold. Coca chewing does not appear to affect temperature regulation as much as it does psychophysiological responses to exercise.

Participants: Michael A. Little and Joel M. Hanna.

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APPENDIX B: PARTICIPANTS

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International Study of Circumpolar Peoples

Eskimos, similar in race, language, and culture across a distance of over 4,000 miles at the top of the world, represent one of the greatest linear dispersions of closely related peoples in the history of mankind. Their habitat, snow-covered for two thirds of the year, is characterized by low temperatures, seasonal extremes in light and darkness, and relatively meager sustaining resources. Despite these environmental constraints, Eskimos have occupied the Arctic for probably 400 generations. Their long-term occupancy in small, kin-based hunting groups provides human biologists with unique opportunities to study in detail certain aspects of human adaptability to a harsh environment. Prior to c. 7,000 B.C., most of our own evolutionary development occurred under similar circumstances in a more southerly setting. The Eskimo way of life is changing radically and rapidly in response to social and economic pressures that are growing with development of mineral and other natural resources in the Eskimos' home territories. Therefore, it is imperative that biological base-line information be obtained before it is too late.

OBJECTIVE

The objective of this program is to describe biological and behavioral processes responsible for the successful adaptation and perpetuation of breeding isolates of Eskimos in northern Alaska.

Villages in northern Alaska were chosen for this study because they have an optimum size for study, the villagers have retained hunting and fishing as a way of life, and information from previous investigations is accessible.

The Alaskan studies are coordinated with IBP studies being conducted in other parts of the Arctic by Danish, French, and Canadian investigators. Methods are comparable, and results can readily be synthesized.

The Director of the program on circumpolar peoples has been on an extended absence. Only the part of the program that is concerned with Eskimos is described in this report.

RESEARCH PLANS

Research on Eskimos has been in five categories. The categories and the main components of each are as follows:

General health and physical fitness Cardiovascular disease, infant morbidity and mortality, and epidemiology

Growth Dentition, size and shape of the body at different ages, and the mineral content of bone

Genetics Population genetics and demography

Behavior Cognition, psychomotor and expressive behavior, and behavioral genetics

Ecology Nutrition and studies of energy flow through the ecosystem of which man is a part

Three years of field research have been conducted. Nineteen scientists started work at Wainwright, Alaska, in July 1968. They were from four American universities, the Alaska State Department of Health, the U.S. Public Health Service, and the University of Milano, Italy.

During the summer of 1968, 91 percent of the Eskimos in Wainwright were examined. Medical examinations included electrocardiographs; X rays of chest, head, wrists, and ankles; tests of the mineral content of bone; blood tests; and throat cultures. Dental examinations included X rays, dental casts, and saliva collections. Respiratory parameters, endurance, and body rhythms were measured. In addition, anthropological materials were collected; they included genealogical data, family histories, and data obtained by photography, anthroposcopy, and anthropometry.

Most investigators used equipment and supplies from their own research laboratories, and subsequent analyses were supported by the home institutions. The Alaska State Department of Health provided X-ray equipment.

A nutritional survey was made in January and February 1969. The investigators estimated amounts of different types of food that were eaten, measured hemoglobin and hematocrit values, and collected (for later laboratory assay) specimens of urine from children of school and preschool age, selected families, and members of the National Guard.

Work was continued in the summer of 1969 with

support from the National Institute of General Medical Sciences. Those participating included dentists, chronobiologists, psychologists, epidemiologists, exercise physiologists, an anthropometrist, a dermataglyphic specialist, a physician, an ophthalmologist, a bone physicist, and a demographer. In addition to carrying out his research, the ophthalmologist, who was from Finland, refracted eyes and prescribed glasses for 50 persons. The Chief of Ophthalmology at the Alaskan Native Health Center in Anchorage provided extra equipment in exchange for these services.

Additional work was done at Anaktuvuk Pass (in the Brooks range), where Wainwrighters have relatives. The anthropologists obtained anthropometric measurements and finger and hand prints of 23 women and 13 men at the village, thus increasing the sample size.

During the summer of 1969 a psychiatrist undertook the first of a series of regular visits to Wainwright, and the chronobiologist continued his work during September.

Frederick A. Milan is Director of the subprogram concerned with the study of Eskimos.

RESEARCH PROGRESS

The following statements about the Eskimo population at Wainwright are based on the work performed in 1968 and 1969.

GENERAL HEALTH

In general, the population is healthy, but the incidence of chronic *otitis media* is high (45 percent of adults, 40 percent of children), and there are marked seasonal fluctuations in upper respiratory infections. Infection from past exposure to pulmonary tuberculosis (45 percent of population) is now controlled chemoprophylactically. Only six persons have chronic diseases; yet infant morbidity and mortality rates are extremely high. Serum cholesteral levels (mg/229.4 ml) are in agreement with levels from the United States.

CARDIOLOGY

Electrocardiograms were sent to the University of Minnesota for standard analysis and computer-compatible coding. Serum cholesterol and triglyceride levels are available and will be correlated with incidence of heart disease. The incidence of atherosclerotic heart disease in natives of Alaska is one eighth that in our population. Electrocardiograms were obtained on this same population in 1955. These data have also been sent to the University of Minnesota for analysis and will provide a good base line for the present study.

SERUM EPIDEMIOLOGY

Two hundred specimens of whole blood (30 ml each) were obtained by venipuncture from all persons between the ages of 6 and 74. All blood samples were slide-typed for blood types A, B, O and MN to aid in later identification. The specimens of whole blood were centrifuged, and the serum was removed asceptically. The serum was distributed in 0.5-ml aliquots and stored in liquid nitrogen. About 2,100 vials of packed red cells and 1,000 vials of plasma were processed and stored in the summer of 1968, and 1,000 vials of plasma were processed and stored in 1969.

Blood specimens were shipped to the New York City Blood Bank for detailed blood type, genetic marker, and enzyme studies. Serum samples (180) were sent to the Case Western Reserve University for study of serum amylase isoenzymes in relation to salivary amylase isoenzymes and typing of immunoglobins. As part of another study, serum samples (185) are being analyzed for C 3 "complement" component at the Department of Medicine, University of Wisconsin. Serum samples (190) were analyzed by the Clinical Chemistry Section, Wisconsin State Laboratory of Hygiene, for standard blood chemistry profiles. Sera (190) are being studied for arborvirus antibodies. Other studies are being undertaken for antibodies of *pertussis*, mononucleosis, measles, mumps, rubella, tularemia, brucellosis (especially *rangiferi*) and mycotic agents. Comparisons will be drawn between these data and data obtained from a comparable study of a native group at Xuixquilucan, state of Mexico, Mexico.

WORK CAPACITY

The physical fitness of 62 Eskimo males (age 6 to 64 years) was evaluated by means of a submaximal step test, by a test to measure maximal anaerobic power, and by a 15-min endurance run. Certain clinical respiratory tests (vital capacity, timed vital capacity, and maximal breathing capacity) were also undertaken.

The results indicate that peak maximal aerobic power of Eskimo males occurs between the ages of 15 and 20 and is similar in magnitude to that of other population groups. The decline of maximal aerobic power with age also is similar to that of other population groups.

Endurance can be measured in a run lasting 15 min. The only instructions are to run as far as possible. Unfortunately, the Eskimos sprinted at the start and exhausted themselves, and their performance could not be evaluated by this method.

Vital capacity and maximal breathing capacity are 10 percent higher in Eskimo males than capacities predicted from height and weight standards for Eskimos in general. The relatively high value of seated height in the ratio between seated height and stature could account for some of this elevation.

In summary, the Eskimo male population is similar to other populations in their capacity to perform aerobic work but above average in their capacity for short bursts of muscular power. It would appear that centuries of adaptation to an arctic hunting life has not led to development of a significantly more efficient oxygen transfer system by these people. Nevertheless, 80 percent of this Eskimo sample are physically fit as compared with a comparable U.S. sample, in which only 20 percent were fit.

CHRONOBIOLOGY

The periodicity of light intensity in the polar region is different from that in the Temperate and Torrid Zones. Light is a primary synchronizer for biological rhythms. At the latitude of Wainwright, direct solar radiation is absent 4 months of the year and present 4 months in summer.

Studies were made to determine the effects of this unusual light-dark cycle on Eskimo body rhythms. Thirteen subjects were studied intensively for a 10-day period before and after each of two solstices and two equinoxes. Physiological observations were made and urine was collected every 2 hr while the subjects were awake. Oral temperature, pulse, blood pressure, eye-hand coordination, and grip strength were measured. Urine samples were analyzed for volume, pH, potassium, sodium, chloride, calcium, and the steriods 17-OHCS and 17-KS. The data were analyzed and rhythm parameters computed by the Periodicity Analysis Laboratories at the University of Minnesota.

Of the data collected during the summer of 1968, only those pertaining to oral temperature, urine potassium, and urine chloride were sufficient to show definite daily rhythms. Data for the entire year are being analyzed for animal rhythms.

OPHTHALMOLOGY

An ophthalmologist examined the eyes of 191 persons for refractive error, iris color, eye disease, color sense, and climatological changes. He made a number of anthropometric measurements, including (1) thickness and breadth of corneal radius and (2) pupillary distance, and he made a number of anthroposcopic observations on the site of iris frill, the existence of embryotoxon corneae posterior (Arcus senilis), the cilioretinal artery, the pigment content of the conjunctiva and eye ground, the form of the palpebral fissure, and the eyelid fold. He took color pictures of the irises and fundi of the eyes of 98 persons.

In this population there were three blind persons, one of whom had narrow angle glaucoma. There were two cases of squint with amblyopia and two cases of color blindness.

Anatomically, the anterior chamber of the eye was shallower than in Europeans but not as shallow as in Eskimos in the Upernavik district of Greenland. A shallow anterior chamber predisposes elderly Eskimos to narrow angle glaucoma. The climatological changes of the conjunctiva, such as development of the pinguecula and changes of the corneal epithelium (band keratitis), were also less pronounced than in the Eskimos in Greenland or the Lapps in Finland.

About 50 of the 308 persons living in the village received prescriptions for new eyeglasses as a side benefit for their cooperation.

GROWTH

Anthropometric Measurements

Anthropometric measurements will be used in characterizing Wainwright Eskimos by their size and shape. They will also be used in comparing Eskimos with non-Eskimo groups and in calculating biological distances between Eskimos in Alaska, Canada, and Greenland. Data from the summer of 1968 will be used as the first intercept of a longitudinal growth study and will be used cross-sectionally in the same study. Physiologists are using skin-fold measurements for calculating lean body mass. Anthropometric data will also be applied to the study of hybridization.

The following general statements about Wainwright Eskimos are based on anthropometric measurements:

- Adult females are only 2 lb lighter than adult males, but they are 10.5 cm shorter in stature.
- Males remain lean and muscular until they are old and average 6 lb less than Caucasian standards. Females tend to put on weight during adolescence and are about 20 lb heavier than Caucasian standards.
- Hybrids of both sexes are taller and heavier than pure Eskimos. A secular growth trend for stature was seen in those born around 1880 as compared with those born in 1940.

Bone Mineral Measurements

Measurements of the mineral content of bone were made by a direct photon absorption method. The monoenergetic radionuclide photon source was ^{125}I. The

shafts of the radii and ulnae of 28 children and 24 adults were scanned for calcium hydroxyapatite.

The bone mineral values for the Eskimo sample were as high as, or higher than, values for U.S. Caucasians of corresponding age and sex. Both Eskimo children and adults, however, had a surprisingly high mineral content relative to their small stature. Two older subjects were osteoporotic, and two others showed signs of diminished bone mineral content.

Dentition

The population may be divided with respect to dental caries into the following groups:

- Older persons. Their teeth are well worn from attrition and abrasion, but with no caries. The teeth of these persons developed before sweets, refined flour, and foods from non-Eskimo sources were readily available.
- Middle-aged persons. Forty-three are toothless because of cariogenic European foods. They have had little dental care.
- Eskimos in school. They have a very high caries rate but are receiving dental care and fluoride treatment regularly from Public Health Service dentists.

Although there were accumulations of debris with heavy deposits of calculus, these did not produce the inflammatory conditions that would have occurred in most other groups.

A high percentage of the population is mandibularly prognathic. This causes difficulty with dentures in later years and results in orthodontic problems peculiar to Eskimo children, who have a Class II malocclusion even at age 2 or 3.

X rays on 91 persons were acceptable for a study of facial and dental patterns. The study was carried out at the Center for Human Growth and Development, University of Michigan. The program consisted of a specially devised measurement system, automatic print-out and card-punching equipment, and a matched-pair program matching each Eskimo with a U.S. Caucasian of the same age and sex. The summary conclusions are as follows:

- The Eskimo mandible is protruded and rotated downward in relation to the facial structure.
- The palatal and lingual inclination of the upper and lower incisors is greater in the Eskimo than in other races.
- Changes in facial patterns by aging and the loss of occlusion are great in the Eskimo.
- The males have larger faces and mandibles than the females.

PSYCHOLOGY

A battery of psychological tests was administered to a group of about 75 persons. One series was concerned with perceptual processes. The qualities tested and the tests used were as follows:

- Spatial visualization; a revision of the Gilford-Zimmerman spatial visualization IV tests
- Ability to identify embedded figures; the embedded figures of Witkin
- Digit span; one of the subtests of the Wechsler Adult Intelligence Scale

Another series was concerned with cognitive processes. The tests used were Raven's Progressive Matrices, Thurstone's Code Aptitude Test, and tests in English and Inupiak (Eskimo) vocabulary.

All necessary translations were prepared at Point Barrow before going to Wainwright. Assistance was received from native Eskimo speakers at the Naval Arctic Research Laboratory.

Although data have not been completely analyzed, certain findings can be reported. No sex difference was found in the responses to the spatial visualization test. A marked sex difference is found in the responses of Caucasians to this kind of test. Data from the mental tests show a slow growth rate that continues to age 20. In contrast, growth ceases at age 16 in the United States. In these tests, the performance of a 16-year-old Eskimo is equivalent to that of a 13-year-old Caucasian in the United States.

GENETICS

Demography

The Wainwright population was 308 in July 1968—169 males (median age 18.6) and 139 females (median age 13.6). There were 67 hybrids, but only three were one half non-Eskimo. Hybridization, which occurred about 1900, was through admixture with New England-based whalers of many racial strains. An average of 10.6 children have been born alive to the 17 postmenopausal women. There are 201 children in 61 sibships. The population has increased more than 3 percent per year over the last 10 years. Nine sets of twins born alive in 364 conceptions yielded a twinning incidence of 27.3 per thousand births—more than twice the incidence of twinning in Caucasian populations in the United States. The male:female ratio for live births was 108.2:100. More male infants died than females, but female out-migration caused the present-day sex ratio favoring males. Only 81 percent of the children born alive have survived beyond age 5. This is in contrast to survival of about 97 percent in the United States. Differential fertility is shown by the fact that one fifth of the women are responsible for almost one half of the living offspring. Intentional birth spacing was not practiced until it was introduced by the U.S. Public Health Service a few years before this

study was begun. A high infant mortality was the only population regulator before introduction of medically supervised contraceptive techniques.

Pedigree analysis, extending from the present through the ascending fourth generation, revealed that 4 out of 32 marriages in the parental generation are consanguineous. These four marriages are: one between second cousins, one between second cousins once removed, and two between first cousins once removed. Sewell Wright's mean coefficient of relationship for the parents is 0.005, a value lying between third cousins and third cousins once removed.

Wright's coefficient of inbreeding was calculated. Calculations using data from pedigree analysis yielded a mean value of 0.004, or equal to third cousins, while data from MN blood groups yielded a value of 0.19, or a value between that for sibs or uncle-niece. The coefficient calculated from blood group data is obviously too high, and pedigree analysis underestimates the consanguinity of the ancestral population.

Dermataglyphs

Finger and palm prints were obtained on 97 males and 112 females at Wainwright, and on 13 males and 21 females at Anaktuvuk Pass. For comparative purposes there are prints on 96 Eskimos from Karluk, Kodiak Island, and about 120 Eskimos and Indians from Alakaket; these were all made earlier. In addition to patterns (radial, ulnar, and whorl), palmar prints will be used to screen for chromosomal aberrations. Karyotype analyses have been undertaken on some of these persons, especially those of Anaktuvuk Pass, by the Battelle Memorial Institute under sponsorship by the Atomic Energy Commission.

Saliva Analysis

Two hundred twenty-one saliva specimens were analyzed for blood group substance. All Eskimos secreted blood group substances in the saliva; 55.6 percent were A, 31.7 percent were O, 7.7 percent were B, and 5.0 percent were AB.

BEHAVIOR

The clinical psychologist of the Alaska Native Health Service has described two related sociopathologies that are constantly seen in working with Eskimos. The first consists of numerous manifestations of physical violence, particularly those of a self-destructive sort, such as suicide, accidents, or child abuse. The second consists of various failures of communication or verbalization, and the substitution of action for words. This leads to a dissociative process in which the connection between meaning and behavior is lost.

The psychiatrist working in this program found four persons at Wainwright with recurrent psychopathologies. These will be screened for EEG abnormalities at the laboratory of the Institute of Arctic Biology in Fairbanks. In addition, serum-bound calcium levels will be followed in a search for evidence of correlations between hypocalcemia and mental disorder.

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APPENDIX B: PARTICIPANTS

Frederick A. Milan, Arctic Health Research Center, U.S. Public Health Service, College, Alaska (Program Director; demography; reproduction and inbreeding)

Fred Allen, Jr., The New York Blood Center, New York, N.Y. (blood group genetics)

T. Bates, Department of Radiology, Medical School, University of Oregon, Portland (medicine)

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B. Boettcher, School of Biological Sciences, The Flinders University of South Australia, Bedford Park, South Australia (salivary amylase)

J. G. Bohlen, NIH Predoctoral Fellow, Human Biology Program, University of Wisconsin, Madison, and Department of Pathology, University of Minnesota Medical School, Minneapolis (chronobiology)
D. Bosman, University of Wisconsin, Madison (preventive medicine)
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Solomon H. Katz, Department of Anthropology, University of Pennsylvania, Philadelphia (medicine)
O. Lee Kline, American Institute of Nutrition, Bethesda, Md. (nutrition)
W. S. Laughlin, Department of Anthropology and Biobehavioral Sciences, University of Connecticut, Storrs (anthropology)
T. Lewin, University of Gothenburg, Sweden (anatomy)
J. Mayhall, Zoller Memorial Dental Clinic, University of Chicago, Chicago, Ill. (dental health and growth)
Richard Mazess, Department of Radiobiology, University of Wisconsin, Madison (anthropology)
D. McLean, University of Chicago (psychology)
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Mary Jane Moore, Graduate Student, Department of Anthropology, University of Wisconsin, Madison (carbonic anhydrase)
Richard H. Osborne, Professor of Anthropology and Medical Genetics, University of Wisconsin, Madison (blood group genetics)
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COORDINATED RESEARCH PROGRAMS

71/72

ENVIRONMENTAL COMPONENT

Biology and Ecology of Nitrogen

Research into the biology and ecology of nitrogen, which is a critical phase of the worldwide effort to provide food and nitrogen for an expanding population, is conducted in accordance with unusual requirements.

It is probable that the methods for providing food and nitrogen a hundred years from now will differ radically from today's methods. For the next 50 years or so, however, it will be necessary to depend primarily on methods now available. The main business of research will be to refine and expand those methods.

Nitrogen is one of the inputs necessary for producing food and, at the same time, is one of the more likely sources of environmental degradation. Thus, there is a great demand for increasing nitrogen utilization in ways that will not degrade the environment.

There are indications that intensive agricultural production by methods followed in many parts of the world today could meet anticipated needs for food and protein production. On some of our more productive lands, these methods entail the input of nitrogen fertilizer at rates 50 to 100 times greater than the nitrogen input rates of native ecosystems. As production potential is maximized, even heavier applications of nitrogenous fertilizers can be anticipated. In many cases the nitrogen harvested with a crop amounts to no more than 20 to 30 percent of that applied, and the remaining nitrogen, usually in the form of nitrate, becomes a potential health hazard in foods and feeds or in streams and aquifers. As such it can be a strong contributor to eutrophication.

The logistics and economics of intensive agriculture tend to favor the input of industrially fixed nitrogen over the use of nitrogenous organic wastes for fertilizer, and the wastes become an additional potential pollutant of the environment. Means for disposing of these wastes must be developed.

A conference on the biology and ecology of nitrogen was held at Davis, California, in November 1967 under the auspices of the U.S./IBP. Discussions were concerned chiefly with (1) the need for a more detailed understanding of the inputs and outputs of fixed nitrogen both in native ecosystems and in agricultural systems, (2) means of efficiently providing adequate quantities of fixed nitrogen, and (3) managing fixed nitrogen in the environment. Investigations concerning some of these matters are under way.

OBJECTIVES

The objectives of the program are as follows:

- To make direct observations on the fixation of nitrogen in representative soils, giving special attention to agricultural soils
- To examine oxygen and nitrous oxide concentrations in deep soil profiles to obtain information on denitrification, paying particular attention to agricultural ecosystems where intensive inputs of fixed nitrogen and other fertilizers are common
- To determine nitrate concentrations in deep profiles of arid soils, paying particular attention to soils that are expected to come under irrigation in the near future and to areas where the presence of underlying concentrations of nitrates might be inferred from geologic evidence
- To organize conferences of workers interested in problems of nitrogen management in agricultural ecosystems, including the problem of disposing of nitrogenous wastes
- To publish and circulate abstracts of work in progress dealing with problems of nitrogen cycling and reactions of the nitrogen cycle
- To coordinate related investigations of nitrogen movement in native ecosystems in the analysis-of-ecosystems program

RESEARCH PLANS

This program includes research on problems of nitrogen management that are not included in other U.S./IBP programs, and it integrates information on nitrogen that is being developed in other programs.

RESEARCH TOPICS

Nitrogen Fixation

Nitrogen fixation by free-living organisms and by symbiotic systems will be evaluated. One procedure will be the direct evaluation of fixation by using isotopic nitrogen and by applying the acetylene-ethylene reaction. Work to date has suggested that the acetylene-ethylene reaction is exceedingly useful as a means of evaluating nitrogen-fixing capabilities, but the calibration between this technique and information gained by direct isotopic means is variable. The two methods must be used in conjunction if reliable information is to be obtained. Isotope-dilution methods can also be employed, but the cost of isotopic nitrogen limits this technique. Should isotopic nitrogen become less expensive, the dilution technique will be used more often.

Denitrification

Where possible, rates of denitrification will be measured directly by isotope-dilution methods. In most cases, however, the significance of denitrification will have to be evaluated by indirect methods and by inference from oxygen and N_2O data.

Nitrates in Groundwaters

The delivery of nitrogenous compounds to groundwaters and to bodies of freshwater will be monitored by direct measurement and by collating data already available.

Oxygen and Nitrous Oxide Determinations

The oxygen and nitrous oxide status of soils in deep profiles will be examined. Sampling will be accomplished primarily by means of capillary plastic tubing connected with equilibration reservoirs at various depths in profile. This method has been selected in preference to direct oxygen electrode determinations because the calibration of the electrodes are unstable with time. Gases from implanted reservoirs can be sampled periodically by a combination of gas chromatographic, infrared, and mass spectrometric measurements. Areas selected for this kind of analysis will include heavily irrigated and heavily fertilized fields. Nitrous oxide is a good presumptive indicator of denitrification activity, and oxygen levels will indicate the likelihood of denitrification. Denitrification probably is not significant at oxygen tensions above 10 mm. Where possible, nitrate levels will be determined in profile to aid in interpretation.

Nitrate Determination in Deep Profile

Work has been done in determining salt content in deep profile. Because of difficulties experienced in determining nitrate content, most of this work has not provided information regarding nitrate. Future studies will require prompt analysis of samples before nitrate losses occur.

COORDINATION AND MANAGEMENT

Conferences

Several conferences are planned in which 15 to 20 workers will be brought together to exchange information and to participate in workshops. They will be held in areas where nitrogen problems are likely to be acute, including the Midwest (intensively managed soils), the Southwest (arid areas near population centers), and urban areas where domestic wastes and the intensive use of nitrogenous fertilizers may contribute to the contamination of water.

Information Exchange

A newsletter and abstracts of research results will be distributed from the University of California, Davis. Distribution will be made initially to laboratories where workers are involved in investigations related to nitrogen. Information for the newsletter will be contributed by the workers.

Management Personnel

The Program Director is C. C. Delwiche, Professor of Geobiology, Department of Soils and Plant Nutrition, University of California, Davis. When funded, the program will be guided by an executive committee consisting of participating research workers.

Biological Control of Insect Pests

The purpose of the program on biological control of insect pests is to study all principles of biological control that can be applied without undue disturbance of the environment. The following principles are among those that will be studied:

- Autocidal techniques
- Biochemical regulation of development and reproduction
- Pheromones, attractants, repellents, and barriers
- Population dynamics
- Plant resistance to attack by insects

The potential of autocidal techniques was shown dramatically by a program in which the Agricultural Research Service (ARS) eradicated the screw-worm fly from the southeastern part of the United States.

The potential of biochemical regulators (hormones) is suggested by the existence in certain phylogenetically ancient plants (e.g., ferns and horsetails) of chemicals that interfere with insect development and by the fact that few insect species have adapted to feed on these plants. The chemicals are similar to insect hormones.

The potential of biochemical messengers (pheromones) is suggested by results obtained in trapping studies in which natural and synthetic pheromones were used. Occurrence of two or more chemicals together can present either a blockage or a synergistic (additive) effect. The complexities of the interaction of the chemicals need extensive study. The effect of the chemicals on natural enemies of the target species also need study.

The role of population dynamics is demonstrated by the control of insect pests by natural enemies, such as predators, parasites, or pathogens. For many pest species there exist somewhere (often right in the same environment) species of natural enemies that are capable of controlling pest densities at levels below those at which serious crop losses result. Where effective enemy species are deterred from exerting their potential roles, or do not exist, enemy species can be introduced. On a worldwide basis, there have been about 250 instances of successful introduction of enemy species. About one third of these are so successful that the threatening species present no problem at all.

OBJECTIVE

The general objective of this program is to utilize all methods of pest control to develop the scientific basis for an integrated method of controlling populations of insect pests at non-economic densities in a manner that optimizes cost-benefit relations and minimizes environmental degradation.

RESEARCH PLANS

This program has two phases. The first is pest-group centered and embraces the use of natural enemies. It is part of an international effort to find better biological means of controlling insects. It is supported by ARS, by state agricultural experiment stations, and by universities. About 30 projects are included in this phase, and they are concerned with four groups of pests: (1) aphids, (2) rice pests and the cereal leaf beetle, (3) spider mites, and (4) scale insects.

The second phase is concerned with a newer, broader effort: integrated control. In this type of control, all compatible measures are used, but the use of pesticides is minimized. The work will be site-centered and crop-centered. The major effort will be made at the population level in agroecosystems. Only in this way can we obtain the information necessary for modeling and for predicting consequences of control measures.

The Program Director is C. B. Huffaker.

RESEARCH METHODS AND PROGRESS

Research progress thus far has been limited to the older of the two phases of the biological control program—the internationally organized phase that is concerned with four groups of pests.

APHIDS

The outstanding development in the aphids project is the establishment of a parasite, *Trioxys pallidus*, from Iran that has proved highly effective in reducing populations of the walnut aphid in California. If expectations are fulfilled, complete biological control can be achieved.

Workers in Minnesota have discovered sources of wild potato germ plasm that is resistant to the aphid *Mysus persicae*. Hybrids from crosses with cultivated potato are being tested in the field by E. B. Radcliffe and F. I. Lauer.

Workers in Washington have reported that natural enemies of a pest can reduce the population of the pest by harassment as well as by parasitization. (See Tamaki *et al.*, 1970, in the appended list of publications.)

RICE STEM BORERS AND THE CEREAL LEAF BEETLE

In the United States, research concerning this group of insects has been concentrated on the cereal leaf beetle. An effort is being made to establish parasites and to develop a computer-oriented program for evaluating their effectiveness.

SPIDER MITES

Development of integrated control programs offer possibilities of considerably reducing the use of pesticides against spider mites on grapes, strawberries, and peaches in California and against apples in Washington. In Washington the use of pesticides has been reduced about 50 percent as a result of the modified program.

Research in California has shown that spider mite infestations on grapes are due largely to the use of pesticides. Cessation of treatments in experimental vineyards has been followed by restoration of satisfactory biological control. Sometimes, however, full restoration is delayed 3 or 4 years as a result of lingering effects of the pesticides on the predators.

A list of key predators that are effective against key spider mites in the United States was developed. Similar lists for other countries are also available.

SCALE INSECTS

Taxonomic studies to untangle some of the complexities of parasites of scale insects have had some success, and various parasites have been exchanged between the United States and other countries. Biological control of the California red scale has been improved.

APPENDIX A: PUBLICATIONS

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Hagen, K. S., and R. van den Bosch. 1968. Impact of pathogens, parasites and predators on aphids. Annu. Rev. Entomol. 13: 325–384.

Hoyt, S. G., and L. E. Caltagirone. In press. The developing programs of integrated control of pests of apples in Washington and peaches in California, ch. 18. *In* C. B. Huffaker [ed.] Biological control. Plenum Press, New York.

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McMurtry, J. A., C. B. Huffaker, and M. van de Vrie. In press. The ecology of tetranychid mites and their natural control. I. The kinds of spider mite enemies, the effects of spray practices on them and their biological properties. Hilgardia.

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van den Bosch, R., B. D. Frazer, C. S. Davis, P. S. Messenger, and R. C. Hom. In press. An effective walnut aphid parasite from Iran. Calif. Agr.

APPENDIX B: PROJECTS AND PRINCIPAL INVESTIGATORS*

Project: Aphids

G. W. Angalet, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 150, Moorestown, N.J. (the role of parasites, predators, and disease in the biological control of the pea aphid in the eastern United States)

H. C. Chiang, Department of Entomology, Fisheries, and Wildlife, University of Minnesota, St. Paul (ecology of predatory insects; trophic relationships of insects found in sugar beet fields; trophic relationships of insects found in the soil in cornfields)

*This list is limited to principal investigators in the phase of the program that is concerned with four groups of pests.

K. S. Hagen, Division of Biological Control, University of California, Berkeley (evaluation of the effectiveness of native natural enemies of the spotted alfalfa aphid and other aphids; evaluation and augmentation of biological control agents to replace or supplement the use of pesticides to control phytophagous arthropod pests)

J. E. Halfhill, Agricultural Research Service, U.S. Department of Agriculture, 3706 West Nob Hill, Yakima, Wash. (biological control of the pea aphid, *Acyrthosiphon pisum* (Harris), through mass propagation and release of its braconid parasites)

Florian I. Lauer, Department of Horticultural Science, University of Minnesota, St. Paul (population dynamics of the green peach aphid, *Myzus persicae*, on potato)

P. S. Messenger, Division of Biological Control, University of California, Berkeley (bioclimatic studies with aphid parasites)

E. B. Radcliffe, Department of Entomology, Fisheries and Wildlife, University of Minnesota, St. Paul (population dynamics of the green peach aphid, *Myzus persicae*, on potato)

R. B. Thurston, Department of Entomology, University of Kentucky, Lexington (population dynamcis of the green peach aphid, *Myzus persicae*, on potato)

R. van den Bosch, Division of Biological Control, University of California, Berkeley (biological control of pest aphids by imported aphidophagous insects)

Project: Rice Pests

H. A. Bess, Department of Entomology, University of Hawaii, Honolulu (biological control of rice pests)

D. L. Haynes, Department of Entomology, Michigan State University, East Lansing (influence of biotic regulatory agents on the population dynamics of the cereal leaf beetle, *Oulema melanoplus*)

K. Nishida, Department of Entomology, University of Hawaii, Honolulu (biological control of rice pests)

J. D. Paschke, Department of Entomology, Purdue University, Lafayette, Ind. (biological control of the cereal leaf beetle, *Oulema melanoplus*)

F. W. Stehr, Department of Entomology, Michigan State University, East Lansing (influence of biotic regulatory agents on the population dynamics of the cereal leaf beetle, *Oulema melanoplus*)

Project: Spider Mites

D. Asquith, Fruit Research Laboratory, Department of Entomology, Pennsylvania State University, Arendtsville (basic research on the suppression of orchard mites with pesticide-resistant predators)

L. E. Caltagirone, Division of Biological Control, University of California, Berkeley (a study of biological control potentials and performance features of predators of spider mites in citrus and deciduous fruit orchards)

H. A. Dean, Department of Entomology, Weslaco Agricultural Experiment Station, Texas A & M University, Weslaco (control of various mite and insect pests of citrus through integration of chemical and biological programs)

D. L. Flaherty, Division of Biological Control, University of California, Berkeley (the role of natural enemies in suppressing spider mites in important food crop ecosystems)

S. G. Hoyt, Department of Entomology, Washington State University, Wenatchee (the effect of short feeding periods and feeding position of *Typhlodromus occidentalis* on mortality and fecundity of *Tetranychus mcdanieli*; the influence of spray programs and cultural practices on the biological control of mites on apples in Washington)

C. B. Huffaker, Division of Biological Control, University of California, Berkeley (basic studies on the dynamics of arthropod populations; the role of natural enemies in suppressing spider mites in important food crop ecosystems)

C. E. Kennett, Division of Biological Control, University of California, Berkeley (a study of biological control potentials and performance features of predators of spider mites in citrus and deciduous fruit orchards; the biology, ecology, and systematics of the phytoseiidae in California)

J. E. Laing, Division of Biological Control, University of California, Berkeley (basic studies on the dynamics of arthropod populations; the role of natural enemies in suppressing spider mites in important food crop ecosystems)

C. W. McCoy, Agricultural Research Service, U.S. Department of Agriculture, Orlando, Fla. (biological control of citrus insects and mites)

J. A. McMurtry, Division of Biological Control, University of California, Riverside (biological control of mites in citrus and avocado)

M. H. Muma, Department of Entomology, University of Florida Citrus Experiment Station, Orlando (spider mite pathogen study; natural control of six-spotted mites; biology of phytoseiidae)

E. R. Oatman, Division of Biological Control, University of California, Riverside (biological control of the two-spotted spider mite on strawberry)

A. G. Selhime, Agricultural Research Service, U.S. Department of Agriculture, Orlando, Fla. (biological control of citrus insects and mites)

Project: Scale Insects

L. E. Caltagirone, Division of Biological Control, University of California, Berkeley (biological control of the olive scale, the San Jose scale, and other armored scales in northern California)

H. A. Dean, Department of Entomology, Weslaco Agricultural Experiment Station, Texas A & M University, Weslaco (control of various mite and insect pests of citrus through integration of chemical and biological programs)

P. DeBach, Division of Biological Control, University of California, Riverside (the role of entomophagous insects in population regulation of armored scale insects (Hymenoptera: Diaspididae) in major world ecosystems; biosystematics and phylogeny of species of *Aphytis* of the world; biological control of red, yellow, purple, and other diaspine scales on citrus, avocado, walnut, and ornamentals)

C. B. Huffaker, Division of Biological Control, University of California, Berkeley (biological control of the olive scale, the San Jose scale, and other armored scales in northern California)

C. E. Kennett, Division of Biological Control, University of California, Berkeley (biological control of the olive scale, the San Jose scale, and other armored scales in northern California)

C. W. McCoy, Agricultural Research Service, U.S. Department of Agriculture, Orlando, Fla. (biological control of citrus insects and mites)

M. F. Schuster, c/o Department of Entomology, Mississippi State University, College Station (biological control of the Rhodes grass scale, *Antonina graminis*, through use of *Neodusmetia sangwani* in Texas)

A. G. Selhime, Agricultural Research Service, U.S. Department of Agriculture, Orlando, Fla. (biological control of citrus insects and mites)

Aerobiology

Aerobiology is the study of biologically significant materials in the atmosphere. These include spores, pollen, pathogenic microbes, minute animals (such as aphids), and noxious gases and other pollutants affecting plants, animals, and man. The aerobiology program promotes multidisciplinary studies that provide an understanding of how the atmospheric transport of biological materials affect ecological systems. In view of the goals of the IBP, the scope of the aerobiology program has been broadened to include the evolutionary development of airborne biological particles as well as productivity of plant ecosystems under the stress of disease caused by airborne pathogens. The IBP provides a unique opportunity to investigate these aerobiology phenomena on a global basis.

Aerobiology was accorded a place in the early plans of section UM. The U.S./IBP effort began with planning in 1966 and 1967 and was soon augmented by the IBP program of the American Phytopathological Society. In April 1969 the aerobiology program received funds for management and general activities and about 1 month later opened a program office in Ann Arbor, Michigan, and a liaison office in Beltsville, Maryland. The program plan was discussed by the American Phytopathological Society at the August 1969 meeting in Spokane, Washington, and by members of the 12th International Botanical Congress in Seattle later in the same month.

An advisory committee, established to guide policy and to review research proposals, held its first meeting in Beltsville on November 20 and 21, 1969. Officers of the phytopathology subprogram met in Washington, D.C., January 28 and 29, 1970, to revise segment objectives and to consider possibilities for funding research proposals. A workshop on plant production losses due to disease was held in St. Paul, Minnesota, February 26–28, 1970. It was attended by representatives of various agencies and institutions of Canada and the United States. The advisory committee held its second meeting on June 2 and 5, 1970, in Raleigh, North Carolina. This coincided with the Raleigh conference described under "Research Progress," below. On June 3 the committee met with the IBP Aerobiology Theme International Working Group, which had been convened on the same occasion.

OBJECTIVES

The objectives of the program are:

- To promote and coordinate internationally oriented research projects in critical areas of aerobiology.
- To develop improved observation techniques and data standardization that will permit comparison of records and information handling systems on an international basis.
- To increase and improve exchange of information between disciplines and between nations.

RESEARCH DESIGN

The program consists of eight discipline-oriented segments representing areas where information is urgently needed: spore loads in the atmosphere, evolution of airborne pathogens, plant production losses due to airborne pathogens, allergenic particles in the atmosphere, phytogeography and genecology of pollen and spores in the atmosphere, human and animal pathogens in the atmosphere, insects and other microfauna in the atmosphere, and effects of gaseous and particulate pollutants on plants and animals. The first three segments constitute the phytopathology subprogram.

William S. Benninghoff, Department of Botany, University of Michigan, Ann Arbor, is Program Director. W. D. McClellan, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland, is director of the phytopathology subprogram. Segment supervisors are as follows:

Spore loads in the atmosphere: Richard D. Schein, College of Science, Pennsylvania State University, University Park

Evolution of airborne pathogens: William Snyder, Department of Pathology, University of California, Berkeley

Plant production losses due to airborne pathogens: Lucas Calpouzos, Department of Plant Pathology, University of Minnesota, St. Paul

Allergenic particles in the atmosphere: William Solomon, University of Michigan Medical Center, Ann Arbor

Phytogeography and genecology of pollen and spores in the atmosphere: William S. Benninghoff (see above)

Human and animal pathogens in the atmosphere: H. F. Hasenclever, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Bethesda, Md.

Insects and other microfauna in the atmosphere: J. Linsley Gressitt, Bernice P. Bishop Museum, Honolulu, Hawaii

Effects of gaseous and particulate pollutants on plants and animals: Howard E. Heggestad, Plant Air Pollution Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

A program coordinator will be appointed to assist the Program Director.

An advisory committee is responsible for guiding the program and for evaluating research proposals. F. A. Wood, Department of Plant Pathology, Pennsylvania State University, University Park, is chairman. The Program Director, the director of the phytopathology subprogram, and the segment supervisors are members. Other members are as follows:

Lester Machta, National Atmospheric and Oceanographic Administration, U.S. Department of Commerce, Silver Spring, Md.

Donald S. Meredith, Department of Plant Pathology, University of Hawaii, Honolulu

Donald H. Pack (alternate for Dr. Machta), National Atmospheric and Oceanographic Administration, U.S. Department of Commerce, Silver Spring, Md.

Carl M. Shy (alternate for Dr. Thompson), National Air Pollution Control Administration, U.S. Department of Health, Education, and Welfare, Durham, N.C.

Jack E. Thompson, National Air Pollution Control Administration, U.S. Department of Health, Education, and Welfare, Durham, N.C.

RESEARCH PROGRESS

The research progress of the aerobiology program consisted of one program-wide conference and of activities associated with the program segments described below. As a service to the researchers in the program, an aerobiology newsletter was established and is being mailed to about 350 scientists in the United States and nine foreign countries.

The program-wide conference, "Aerobiology Objectives in Atmospheric Monitoring," was held at Raleigh, North Carolina, in June 1970 and involved 65 persons from 5 countries, 10 government agencies, and 11 universities. This conference was sponsored by the aerobiology program and the National Air Pollution Control Administration. The chief accomplishments were: (1) a review of the current status of atmospheric monitoring programs, (2) identification of needed aerobiological information, and (3) development of recommendations for improving present monitoring systems. A report on the conference is being prepared for publication.

SPORE LOADS IN THE ATMOSPHERE

This segment is concerned with dissemination of plant pathogens. The research is concentrated on release, transport, and viability of propagules.

Air Spora in Hawaii

Diurnal and seasonal periodicities of airborne fungi have been recorded in papaya, macadamia, and banana plantations in Hawaii. Periodicities have been related to specific plant diseases, nature of vegetation in areas sampled, and meteorological conditions. Preliminary studies have been made on abundance and fluctuations in numbers of possible allergens in residential areas. Cooperation has been established with the Department of Agriculture, Fiji, for comparison of airborne particles in banana plantations in Fiji and Hawaii.

Supported by National Institutes of Health.

Principal investigators: Ivan W. Buddenhagen and Donald S. Meredith, Department of Plant Pathology, University of Hawaii, Honolulu

Inoculum Production, Dissemination, and Infection by *Scirrhia* (*Dothistroma*) *pini*

Submitted for funding.

Principal investigator: Fields W. Cobb, Jr., Department of Plant Pathology, University of California, Berkeley

The Relationship of Origin and Variability to Pathogenicity and Morphology of *Fusarium roseum*

Work on this project is under way. Arrangements have been made for cooperative work on Fusaria in Australia.

Submitted for funding.

Principal investigator: Paul E. Nelson, Department of

Plant Pathology, Pennsylvania State University, University Park

EVOLUTION OF AIRBORNE PATHOGENS

This segment is concerned with investigation on a world basis of the origin of plant pathogens and diseases, the origin and distribution of inoculum and genes for pathogenicity, and the evolution of pathogenicity.

Origin and Spread of Airborne Inoculum of *Fusarium* Pathogens

Related studies on Fusarium ecology indicate that the perithecial (airborne) stages of Fusarium species occur only in certain regions. To date, we have established probable major sources for three species, as follows:

Gibberella (*Fusarium*) *moniliforme*–South Pacific
Calonectria (*Fusarium*) *rigiduiscala*–American tropics
Hypomyces (*Fusarium*) *solani*–Japan and Africa

Excellent cooperation has been established with scientists in Asia, Central America, and South America.

Submitted for funding.

Principal investigators: William C. Snyder, J. G. Hancock, and S. N. Smith, Department of Plant Pathology, University of California, Berkeley

Species and Biotypes of the Nematode Genus *Meloidogyne* (Root-Knot Nematodes) and Closely Related Genera

The principal investigator visited scientists and administrators of the International Institute of Tropical Agriculture in Ibadan, Nigeria, from December 1 to 18, 1969. A cooperative research program on the root-knot nematodes for that part of the world was initiated. In Nigeria and Peru the investigator discussed the possibility of a cooperative effort on the part of local institutions and North Carolina State University to enhance professional and subprofessional competence in nematology.

Submitted for funding.

Principal investigator: J. N. Sasser, Department of Plant Pathology, North Carolina State University, Raleigh

Origin and Distribution of *Rhizoctonia* in Relation to the Evolution and Spread of Pathogenically Specialized Forms

Techniques for identifying pathogenic groupings have been developed, and the investigators have worked with the Waite Agricultural Research Institute in South Australia in perfecting the techniques. Commitments for cooperation have been obtained from Iran, Chile, Central America, Malaysia, Japan, Puerto Rico, and a number of U.S. and European workers.

Submitted for funding.

Principal investigators: John R. Parmeter, Jr., and A. R. Weinhold, Department of Phytopathology, University of California, Berkeley

Origin and Distribution of Species of *Phytophthora*

Phytophthora cultures have been obtained from West Africa, Mexico, Guatemala, Costa Rica, and Panama, and some of these have been tested for compatibility type and for variation in pathogenicity. Contacts for collaboration have been established in Ghana, Nigeria, Ivory Coast, France, Brazil, Trinidad, Puerto Rico, Colombia, Panama, and Costa Rica.

Submitted for funding.

Principal investigators: George A. Zentmyer, Donald C. Erwin, and Peter H. Tsao, Department of Plant Pathology, University of California, Riverside

PLANT PRODUCTION LOSSES DUE TO AIRBORNE PATHOGENS

The objectives of this segment are to improve methods of assessing plant production losses due to diseases caused by airborne pathogens.

A workshop on methodology for measuring plant production losses due to disease was held February 26 and 27, 1970, in St. Paul, Minnesota. Twelve scientists from the United States and Canada evaluated the research design, techniques, and interpretations of current work.

Yield Losses in Spring Wheat Caused by *Puccinia recondita* and *Puccinia graminis tritici* in Different Environments

A field experiment with nine spring wheat varieties and four patterns of disease epidemics (stem rust, leaf rust, or both rusts) was carried out in Minnesota, Colorado, and Puerto Rico to determine whether there is a predictable relationship between disease and loss of yield in different environments. Data are being analyzed for correlations between severity of disease at different stages of wheat development and percentage of loss of

yield. A small workshop on plant losses due to disease was held in St. Paul, Minnesota, in February 1970.

Communication has been established with scientists in Canada, the United Kingdom, the Netherlands, and Italy regarding the results of this experiment. Negotiations are in progress to obtain experimental sites in the Netherlands and Yugoslavia.

Supported by Agricultural Research Service, U.S. Department of Agriculture.

Principal investigator: Lucas Calpouzos, Department of Plant Pathology, University of Minnesota, St. Paul

ALLERGENIC PARTICLES IN THE ATMOSPHERE

This segment seeks to evaluate the status of research on airborne allergens, bring ongoing projects into effective association and stimulate needed research.

There are a number of conditions that make it desirable to perform additional research. They include:

- Lack of pollen concentration data for all but a few points in this country and Great Britain
- The obscurity of the contributions of local pollen sources (especially trees) to the pollen exposure in any given locality
- Uncertainty regarding the pollen emissions of closely related plant species
- Lack of information concerning the effects of ultraviolet light and gaseous atmospheric pollutants on particle allergenicity
- Lack of information concerning the prevalence of bacteria, algae, and insect debris in indoor and outdoor air
- Lack of information on the exposure potential during normal human activity

PHYTOGEOGRAPHY AND GENECOLOGY OF POLLEN AND SPORES IN THE ATMOSPHERE

Several pilot projects are in progress. Donald A. Jameson, Director, Pawnee Site, Grasslands Biome, analysis-of-ecosystems program, has requested assistance in measuring the import and export of humus by wind action at the grassland study sites. Sampling devices and systems for this problem are being developed.

Devices that measure concentrations of pollen, especially instantaneous concentrations, are being studied.

A photographic atlas of fungus spores is under consideration. Specialists in mycological systematics are being consulted.

Viable Species of Algae and Protozoa in the Atmosphere

Submitted for funding.

Principal investigator: Harold E. Schlichting, Jr., Department of Botany, North Carolina State University, Raleigh

HUMAN AND ANIMAL PATHOGENS IN THE ATMOSPHERE

This segment is providing liaison between research in the microbiology-medical mycology area and the aerobiology program.

INSECTS AND OTHER MICROFAUNA IN THE ATMOSPHERE

This segment is concerned with the atmospheric dispersal of minute animals, such as aphids, leafhoppers, and locusts, some of which are vectors of disease.

Natural Dispersal of Insects in the Arctic

In the summer of 1969, several thousand specimens of insects and other arthropods were trapped in large nylon nets set out on the tundra near Point Barrow, Alaska, and some were trapped at Cape Thompson. Additional trap-nets mounted on a NASA tower near Point Barrow, set for long-distance dispersants, produced only a few specimens. Wind and other weather data are correlated with the trapping results. A paper on these results, and on results obtained by Dr. C. Yoshimoto and assistant in 1965, is in preparation.

Supported by Arctic Institute of North America.

Principal investigators: J. Linsley Gressitt and Eugene Holzapfel, Bernice P. Bishop Museum, Honolulu, Hawaii

Studies of Airborne Insects in the Atmosphere

Large numbers of insects have been trapped from ships in many parts of the Pacific Ocean and in other oceans. Cooperation has been received from individuals and organizations in various other countries, including Denmark, England, Chile, and New Zealand. Results of some of this work are being published in *Pacific Insects*.

Supported by Oceanography Branch, Office of Naval Research, U.S. Navy.

Principal investigators: J. Linsley Gressitt and Eugene Holzapfel, Bernice P. Bishop Museum, Honolulu, Hawaii

EFFECTS OF GASEOUS AND PARTICULATE POLLUTANTS ON PLANTS AND ANIMALS

Objectives:

- To collect, on a worldwide basis, information on levels of total oxidants, sulphur oxides, nitrogen oxides, fluorides, hydrocarbons, ethylene, lead, cadmium, and boron and to determine how the materials were measured
- To collect information on losses to vegetation and animals attributable to air pollutants

The objectives are shared with federal and state government laboratories, industrial laboratories, and academic laboratories in the United States and other nations. The collected information will be exchanged with other nations, and an effort will be made toward uniformity of report procedures and notations.

This segment has furnished advice on design of research projects to predoctoral and postdoctoral investigators and has complied with many requests for information from persons outside this research field.

Air Pollution Effects on Powdery Mildew Fungi

Methods have been developed for producing viable conidia of *Microsphaera alni* and *Erysiphe graminis*, for transferring conidia directly from hosts to test membranes with a vacuum spore collector, for even deposition of conidia onto substrates in a settling tower, and for germination under controlled temperature and humidity conditions. An ozone exposure apparatus has been devised for simultaneously exposing conidia to various concentration-time doses of gases and to filtered air. Investigations are in progress on the mechanism of induced resistance of leaf tissue adjacent to mildew colonies when the tissue is exposed to high concentrations of ozone.

Supported by National Air Pollution Control Administration.

Principal investigator: Craig R. Hibben, Kitchawan Research Laboratory, Brooklyn Botanic Garden, Ossining, N.Y.

Phenology

Man has always been alert to the natural events that take place in his immediate surroundings. In past ages knowledge of these events was essential to his survival. Today, even more than in the past, man must know, understand, and record the periodic seasonal changes that occur in plants and animals. These changes are collectively termed the phenology of the organisms.

The vegetative season varies from year to year, and this variation has a profound effect on man and his ability to produce food. Yet, because so little information has been accumulated, the variations cannot be mapped in detail. Data on cultivated crops are available but are biased by human manipulation.

Where sufficiently intensive studies have been made, phenological observations may be used for microclimatic mapping. In the Wingra Lake Basin, Wisconsin, phenological data from the University of Wisconsin Arboretum will be used to make phenological maps indicating microclimatic conditions affecting productivity in that system. Microclimatic maps derived from phenological data can also be used to indicate the rates at which soil moisture is depleted by evaporation.

Wherever the responses of plants or animals to heat, light, precipitation, or other factors are observed, phenological data are part of the record for practical and scientific purposes. Examples of applications are given in Table 1.

TABLE 1 Examples of Applications for Phenological Data

Related Sciences	Practical Applications	Research Applications
Physical sciences		
Climatology	Plants as indicators of microclimate	Microclimatic mapping
Limnology	Duration of ice-cover, prediction of algal blooms	Eutrophication trends
Soil science	Plants as indicators of soil moisture	Trafficability, evaporativity, weather modification
Agricultural sciences		
Agronomy	Timing of field operations	Remote sensing of crops for growth characteristics
Apiculture	Timing of transplantation of hives	Prediction of flowering events
Horticulture	Timing of propagation	Development of adapted varieties
Plant genetics	Timing of seed collection and growing season adaptation	Temporal and regional changes in hereditary traits
Plant pathology	Timing of spraying	Pest control through natural enemies
Forestry	Timing of Christmas tree shearing, choice of planting sites	Remote sensing of growth stages and development of adapted species
Life sciences		
Biology	Ecological relationships	Investigation of adaptation to environments and evolution
Entomology	Pest control	Insect development and migration
Medicine	Prediction of onset of hay fever and allergies produced by plants	Correlation of events with indicator plants
Pharmacology	Timing of collecting plants used in drugs and spices	Correlation of development with indicator plants

OBJECTIVES

The objectives of the phenology program are to develop phenology as a viable science in North America; to elucidate phenological relationships with applications in the physical, agricultural, and life sciences; to assist in integrating IBP research; and to stimulate and coordinate intensive phenological research on mechanisms of phenological response.

RESEARCH PLANS

The phenology program is directed by Forest Stearns. The program is in four parts, each of which has a coordinator:

- Regional phenological networks (Byron O. Blair)
- Standardization of observations and data handling (Mrs. Katherine Lettau)
- Intensive studies on specific phenological phenomena and on mechanisms underlying phenological responses (Richard J. Hopp)
- International cooperation (Richard J. Hopp)

NETWORKS

Three regional phenological networks—northeastern, north central, and western—are operating in the United States. They are funded by cooperative regional projects of the state agricultural experiment stations and are coordinated through regional committees. In cooperation with the northeastern project, phenological observations are now being extended southward.

STANDARDS

Phenological observations must be defined and standardized if data are to be compared. Standards have been developed for lilac and honeysuckle, but much remains to be done for a wide range of other species. Handbooks for observers are planned both for the phenological garden network and for a variety of native species.

A major deficiency in earlier studies was the inability to make data readily available to persons wishing to analyze them. Some early data were published. However, a considerable amount of useful data gathered at agricultural experiment stations, U.S. Forest Service laboratories, and other research organizations is available only in research files. The development of a system for acquiring and retrieving data is an important secondary objective.

INTENSIVE STUDIES

Intensive studies of the phenology of particular species long antedate the IBP, as do studies of the physiological basis of plant and animal responses to phenologically active stimuli. The phenology program is encouraging additional studies both in intensive investigations of particular species and in the mechanisms of phenological response.

INTERNATIONAL COOPERATION

Phenological work in the United States is drawing upon the experience and techniques of networks established in Europe and elsewhere. Efforts are being made to exchange study material between continents and to assist in establishing cooperative gardens.

RESEARCH PROGRESS

OBSERVATION NETWORKS

To be useful as a phenological indicator, a plant must have certain characteristics: relatively conspicuous and well-defined developmental phases, timing of development in tune with agricultural species of value, long life and adaptation to a wide range of climates, marked response to the meteorological environment, and relative ease of vegetative propagation. The lilac meets these specifications. An additional advantage is that lilacs are established in a great many locations. Thus, the lilac is a suitable object for phenological observations.

Honeysuckles of two cultivars were selected to extend the phenological network in the western region. These cultivars have broad geographic adaptation and are long-lived, easily propagated, and relatively free from diseases and insects. They can be observed only 1 year after planting. Honeysuckle shows nine distinct phenophases, which in sequence extend over most of the growing season. Caprio *et al.* (1970) describe them as "a precise and versatile climatological instrument."

At present, studies depend on observations of lilac in the northeastern and north central regions and on observations of honeysuckle and lilac in the western region. These regional projects are mapping phenologically de-

termined environmental zones and examining some of the mechanisms of phenological response.

Northeastern Region

The Vermont Agricultural Experiment Station has assumed leadership in the northeastern network, which includes about 200 sites in 13 states. The dates of several phenological events are recorded each year, and a manual for phenological observations has been prepared and distributed to cooperators (Hopp *et al.*, 1969).

Temperature summations to the dates of phenological events have been calculated for a number of sites. A base temperature of 32° F appears to result in a smaller coefficient of variation than do higher base temperatures. January 1 was tentatively used as the starting date for temperature accumulation. The results to date are encouraging since they appear to be supported by studies conducted under controlled conditions. A detailed study related to this project was conducted in New Jersey and Michigan in 1969. It resulted in a method for predicting harvest dates for blueberries (Addison, 1969).

North Central Region*

In the north central region (12 states), plantings of Persian lilac were established at 51 stations. The plantings were observed at three stages: opening of the first leaf bud, full bloom, and end of bloom. These data are being summarized and evaluated.

In Indiana, the lilac network has been expanded into phenological gardens consisting of 15 to 20 species of both wild and cultivated plants. Twelve gardens, four of which have major meteorological facilities, have been established in that state since 1964. Data are available on 10 species in 10 locations for 1968 and 1969. One garden is functional in Wisconsin.

The 12 gardens in Indiana grow shrubs, semishrubs, grasses, and perennial forbs. All plants were started by cuttings or by clonal propagation from original sources; hence, genetic variation is eliminated. The several species provide a flowering range from early April to mid-September. Flowering varies from north to south in Indiana by as much as 3 weeks in the spring-flowering species and a week to 10 days in the fall-flowering species. Variations in soil and microclimate are considered. Tentative conclusions drawn from data of the last several years are:

- Species growing directly from the soil surface each year are influenced primarily by subsurface soil temperature.
- Species with woody structures are influenced by air temperature at screen height and, if they are growing in heavy soils, by diurnal soil-temperature patterns at about 20 inches deep.

Fifty-five parameters of microclimate of potential phenological value have been examined statistically, and considerable insight in using analytical techniques has been gained.

In 1968, rye (*Secale cereale*) was planted at seven stations in Indiana. The performance of this species suggests that it may provide data relating directly to the actual and predicted performance of agricultural crops in various parts of the state.

Western Region

In the western United States a strong phenological program is functioning under the leadership of Montana State University. Nineteen publications have been issued, including an exceptionally thorough phenological analysis of lilac (Caprio, 1966). The western lilac phenology project includes data from almost 1,000 observation sites in 12 states. Results indicate the usefulness of long-term phenological data for studying the variations in growth patterns from one year to the next and for examining the extent of the long-term variability in seasons (Caprio and Metcalf, 1970). Analysis of the data is expected to show how variability of weather and of phenological events observed in lilac and certain other species is related to variability of growth in wheat and barley.

In addition to lilac, two genotypes of honeysuckle have been planted at each of 2,000 observation sites. Honeysuckle stock is being introduced into the midwestern and eastern networks. Guides for observing honeysuckle and lilac have been issued (Caprio, 1968; Hopp *et al.*, 1969; Caprio *et al.*, 1970).

Phenological data are available with which to draw detailed maps showing dates when the purple common lilac begins normally to bloom in each of 11 western states. A map for Montana has been published (Caprio, 1966), but funds are not available for publishing maps for other states.

Cropping hazards are found to be higher in areas in which lilac blooming dates are variable than they are in areas in which the dates are constant.

Southern Region

A phenological network has been developed to provide data on several species in North Carolina. Results of early studies have been presented in computer-drawn maps (Lieth and Radford, 1971). Lilac phenology is not

*On July 1, 1970, the phenology efforts conducted previously under the separate regional research projects in the north central and northeastern states were combined and expanded into a new project (NE 69). This project will include the original programs described herein and the phenological programs that are being developed in Alaska, Mississippi, North Carolina, and the Canadian province of Quebec.

reliable south of West Virginia, and other species suitable for phenological observations farther south will be selected. Plants with sharp distinctive phenophases are being sought (Lieth, 1970). Species suitable for aerial observation, such as flowering dogwood (*Cornus florida*), may be extremely useful for correlating remote sensing data with regional phenological development.

INTENSIVE STUDIES

University and government scientists are conducting phenological studies that differ from the regional network studies in that they are concerned with plant behavior in a small area or with understanding phenological responses. Those described below are representative of those included in the U.S./IBP phenology program.

Ecological Effects of Weather Modification

Phenological data and productivity data were collected at weekly intervals during the growing season at two sites 4,700 and 7,800 ft above sea level. Differences in development between species occurring in the same area under varying moisture conditions (snow depth) were evident, as were differences between the two areas. Additional precipitation (snow) delays the emergence and flowering of many species (Donald Collins, personal communication).

Phenology and Forest Genetics

Forest geneticists must understand the relationship between (1) budbreak and late frost in spring and (2) timing of the development of male and female cones. Timing of opening of the vegetative bud is one of the most critical factors in the growth of the white spruce seedling. If the bud opens too soon, the young, tender needles are exposed to late frosts, and the exposure kills the terminal growth. The breeder's objective is to avoid frost damage by selecting fast-growing clones, which produce late-flushing buds. Forest Service investigators in Wisconsin observed flushing and growth of 27 progenies in the greenhouse and correlated these results with phenological observations in the field. Field observations had previously indicated that in northern Wisconsin frost might kill buds as often as three times in one spring and might occur in certain planting sites as late as early July.

Analysis of the phenology of budbreak suggests that control of this event is a function of temperature and the genetic constitution of the tree. Differences in temperature summation from one spring to another cause differences of as much as 2 weeks in dates of budbreak.

Knowing the origin of seeds does not always make it possible to know what the date of flushing will be. Seeds from the same source often produce trees that differ considerably from one another. A relationship between flushing time and growth rate is indicated by the fact that late-flushing genotypes show a somewhat faster growth rate. Knowledge of the variation in flushing dates and of the genetic makeup of the seedlings is necessary to determine the degree of genetic control and the relationships between flushing time and temperature summation (Nienstaedt and King, 1969).

In central Alberta, seasonal height growth of white spruce seedlings appears to be correlated both with the length of the growing period and with two morphological characteristics of the plant: size of the terminal bud and height of the seedling (Hellum, 1967). The taller the seedling the later the setting of the bud.

Tropical Forest Phenology

In the period 1968–1970, Gordon W. Frankie made observations in Costa Rica on the phenology of several hundred mounted specimens of about 160 species of woody plants that grew in the lowland wet forest at Finca La Selva, Heredia province, and in the lowland dry forest at Palo Verde, Granacaste Province. The results are being prepared for publication. The generalization by Janzen (1967) that flowering in the highly seasonal climate of Granacaste is concentrated in the dry season is shown to be incomplete. At Palo Verde 35 species flowered in the dry season, 36 in the wet season, and 13 in both seasons. The flowers that appear in the dry season tend to be more conspicuous than those that appear in the wet season. Most trees mature their fruits in the dry season. Correlations are being worked out between the phenology of the woody plants and their pollination systems, their seed dispersal systems, and the circumstances of their seedling establishment. This activity, in which H. G. Baker is the principal investigator, is part of an ecosystem comparison study sponsored by the Organization for Tropical Studies with the aid of a grant from the National Science Foundation.

Root and Shoot Phenology

Study of the phenology of root growth and leaf development is providing a better understanding of the relationship between two major northern hardwood forest tree species: yellow birch (*Betula lutea*) and sugar maple (*Acer saccharum*). Sugar maple root activity is at a peak early in spring while leaves are expanding. The beginning of root activity in yellow birch may lag behind that of sugar maple by as much as 2 weeks, and peak root activity may lag as much as a month. These two species are competitors, and knowledge of their relationship in the northern hardwood forest is critical in forest management. Sugar maple may have a competitive advantage over faster-growing species as a result of early root growth (C. Tubbs, personal communication). Phenologi-

cal studies of roots are being continued to relate the beginning and continuation of root activity to environmental factors. If a correlation is found, it may be possible to predict patterns of root activity without making observations.

Effect of Fertilization on Phenological Events

A study in the northern Great Plains is relating crop phenology to the application rates of nitrogen on range sites. Knowledge of the effects of fertilization on phenological events would make it possible to use both fertilizer and native grassland range more efficiently. One benefit might be a reduction in frost damage. For example, if a farmer knew that heavy applications of nitrogen to grass would result in the emergence of tender growth when frost was expected, he could reduce the likelihood of frost damage by applying nitrogen at lower rates. Long-term phenological data may also provide information by which the quality of range sites can be categorized (Goetz, 1969). Adding fertilizer to a native grassland can increase utilization by livestock. Many species of plants are present in native grasslands. The timing of phenological development of the various species must be known so that the most desirable plants receive the benefit of the fertilizer. There is a related need for a more fundamental understanding of the morphology of native grasses and their response to grazing (Green, 1969).

Phenology in Ecosystems

Phenological data often may be substituted for other biological data or for meteorological data. For instance, the deciduous forest biome study in the Lake Wingra Basin (IBP) will use phenological data from the University of Wisconsin Arboretum and nearby areas to compare and coordinate seasonally related sequences of various ecological processes at different points within the basin.* Phenological data are easier and cheaper to obtain than are meteorological data. The considerable body of data available for analysis will be supplemented with information from the Wisconsin Phenological Society and from investigations on vegetation and mesoclimate.†

The coordinated study of phenology is a step toward prediction of primary production in all the biomes included in the IBP analysis-of-ecosystems program. Sites may be related by phenological events, differences in length of the growing season, and limiting factors, all of which will be monitored.

*J. A. Zimmerman. 1969. "A 35-Year Record of Selected Spring Events at Madison, Wisconsin, 1935–1969." Presented at 1969 meeting of the Wisconsin Academy of Sciences, Arts and Letters.

†O. L. Loucks and Nancy Knight. 1968. "The Mesoclimate of Wisconsin in Relation to Natural Vegetation." Final report of the project in environmental sciences. University of Wisconsin.

Studies similar to those in the Lake Wingra Basin have been initiated at Oak Ridge, Tennessee. Information is being accumulated to permit the selection of phenological indicator events. Records for the first 7 years have been published (Taylor, 1969).

Phenological studies are planned in the Lake George watershed, another area included in the deciduous forest biome program. The observations of established species will be keyed to those at Lake Wingra and Oak Ridge, sites in the northeastern lilac network, and Indiana and other midwestern bench-mark stations.

In the Texas grasslands, observations are being made on vegetation, reproductive stages, and phenology as related to climate and soil moisture. Initial work in Nevada suggests that differences in timing of events in that region are due primarily to site and precipitation and secondarily to relationships between development rate, soil moisture depletion, and soil temperature. In the cold desert, the overriding influence on phenology appears to be the precipitation-soil moisture factor. Thus, there are regional differences in the major factors controlling phenological events (Bro. Daniel Lynch and Paul Tueller, personal communications).

Relationships between Insect and Plant Development

The studies reported in the preceding sections are concerned with plants and plant development. Phenological information is also being obtained on animals, birds, and insects and on relationships between plants and insects. In Wisconsin the developmental sequencing of several mosquito species was studied in relation to the development of a variety of plant indicator species. Preliminary results suggest that the time of appearance of certain mosquitoes and other Diptera may be signaled by the development of certain plant phases (DeFoliart *et al.*, 1967).

In Texas the first emergence of *Culex Tarsalis* females appears correlated with the flowering of spike rush and tansey mustard, and the first isolations of encephalitis from sparrows were correlated with the first appearance of chimney swifts and with initial flowering of several plants (e.g., arrowhead, curly dock, and pink smartweed). Preliminary data suggest that there may be worthwhile correlations between important stages in the seasonal history of arboviruses and phenological phenomena of birds and plants within the same ecosystem (A. D. Hess, personal communication).

Bird and Animal Phenology

Other studies are investigating the phenology of animal development relative to climate. A study of the movement of blackbird populations in northern Ohio provides data both on the sequence of movements by

these birds and on timing of these movements relative to climatic conditions and vegetational development. A study on the reproductive phenology of redwing blackbirds in upland habitats is in progress. It examines the effect of microclimate on laying, nest construction, and nesting development. Results will enable wildlife management specialists to make predictions about the effect of weather on nesting and on the survival of nestlings (M. I. Dyer, personal communication).

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Conservation of Plant Genetic Materials

Modern crop husbandry is based on a relatively small segment of the plant kingdom. These highly efficient products of man's research, however, still depend on the genetic resources that occur in the "gene centers" of the world. Gene centers may be either the regions that represent the geographic origin of the species or areas where primitive varieties have been grown. Many of these progenitor types or weedy relatives of crops have been the principal sources of pest resistance or other essential traits.

Gene pools are seriously threatened with destruction, by overgrazing and related malpractice, and with loss through replacement of "land races" by improved varieties. Once the primitive races are destroyed or replaced, they can never be recovered.

Recognizing that these resources are essential to agriculture in advanced and developing countries alike, international organizations concerned with food production encourage the development of national efforts under the International Biological Program (IBP) to attack the problem of dwindling germ plasm reserves in a coordinated fashion.

Except for sunflower and some minor crops, the United States does not have a natural base of crop germ plasm. Since our nation's beginning, we have had free access to the world's germ plasm, and we have made greater use of introduced species and varieties than has any other nation. Now when there is an urgent need to ensure continuance of the availability of these resources, we find that agricultural practices may restrict or obliterate them.

In September 1967 the Food and Agriculture Organization of the United Nations (FAO) and the IBP sponsored an international technical conference to determine courses of action to conserve crop germ plasm. The conference found that a world survey of threatened germ plasm should be conducted, that appropriate institutions should serve as centers for advanced training in plant exploration and collection, and that international programs for storing and retrieving genetic information relating to germ plasm collections should be encouraged.

In 1969 and 1970 FAO held conferences in Rome to develop plans initiated at the 1967 conference. These conferences resulted in formation of an FAO Crop Ecology and Genetic Resources Branch with headquarters in Rome. This unit coordinates international efforts in germ plasm conservation.

In 1968 a symposium on germ plasm was held as a part of a meeting of the American Institute of Biological Sciences at Columbus, Ohio. About 10 papers were presented on the status of the germ plasm base in the United States and on possibilities of conserving the base through participation in the IBP. The papers were published in *Economic Botany* 23:4 (1969).

In December 1969 the U.S. National Committee for the IBP recommended that an integrated research program on conservation of plant genetic materials be included in the U.S./IBP. The Director of the Program is John Creech.

OBJECTIVES

The objectives are:

- To conduct national surveys of primitive and wild plant genetic resources held in the United States and to determine the scope, quality, and usefulness of these resources
- To make full use of automatic data processing techniques in assembling information gained in the surveys and in analyzing, storing, and retrieving it
- To disseminate results of the surveys to IBP, FAO, the Agency for International Development (AID), and other organizations
- To cooperate in national programs to use and perpetuate our plant genetic resources
- To cooperate with IBP, FAO, AID, and other organizations in developing priorities for collecting germ plasm in threatened biological and geographical areas

RESEARCH PLANS

This program consists of three activities: surveys of collections, data handling, and conservation and use of germ plasm.

SURVEYS OF COLLECTIONS

Surveys of collections of genetic stocks in federal, state, and private institutions are required as a basis for assessing the need for exploration and accumulation of germ plasm. FAO will integrate the surveys in the United States with similar surveys in other countries. Thus, the United States will have inventories of stocks in this country and will have access to information gathered in other countries.

The information compiled by this program makes possible research on centers of diversity and broadens our understanding of the movement to and establishment of crops in secondary centers of diversity and other aspects of man's effects on crop dispersal.

DATA HANDLING

To be of maximum usefulness, data concerning collections of genetic stocks must be handled through automatic data processing techniques. The program on conservation of plant genetic materials has equipment for accumulating information, analyzing it, and preparing printouts. The printouts will provide information on variations in collections, on sources of germ plasm, and on geographic patterns of resistance to diseases and insects. Information thus made available is an aid in establishing priorities for plant exploration and in identifying gaps in our germ plasm base.

CONSERVATION AND USE OF GERM PLASM

The purpose of a gene pool program is to provide large blocks of germ plasm to breeders. This variety of genetic stock may be required to counteract disease outbreaks or to upgrade crop quality and yield in long-term breeding programs.

Conserved germ plasm is divided into two categories on the basis of accessibility: (1) working stocks (world collections) held in adequate storage and available when needed and (2) reserve stocks held in such facilities as the National Seed Storage Laboratory, Fort Collins, Colorado, for long-term preservation. The reserve stocks are held under optimum conditions to ensure long-term viability and are released only when working stocks are unavailable. A reserve storage includes all crops, while working stocks are usually restricted to single crops.

RESEARCH METHODS AND PROGRESS

The Agricultural Research Service (ARS), in cooperation with AID, has developed programs in Puerto Rico and elsewhere for assembling, evaluating, and distributing breeding stocks of edible yams and other root crops. Similar programs are under way on pulses (edible legumes) and sorghums. Each program uses existing collections of seed or vegetative stocks and expands on these bases through exchange or collection of additional stocks. The goal is to provide authentic, disease-free breeding materials.

The Rockefeller Foundation, in cooperation with ARS and several private institutions, has initiated national surveys of wheat, corn, sorghum, and rice. In keeping with plans for a global network of breeding research to upgrade crop production in developing countries, the foundation has initiated a program to increase pulse germ plasm.

ARS, in cooperation with FAO, the Rockefeller Foundation, and other agencies, is assessing the need for additions to existing wheat collections. A statement of procedure has been accepted. The existing wheat collections lack some varieties from the Near East, and plans are being developed to collect some of these varieties.

The world collections of sorghum are inadequate and incomplete. The most serious deficiencies are lack of wild and weedy races, incomplete collections in Ethiopia and Sudan, a poor collection of Chinese kaoliangs, gaps in the African collection, few collections from West Pakistan, poor collections from Southeast Asia, poor representation of grassy and fodder types, and lack of collections of species in other sections of the genus. Uncollected germ plasm is threatened, but the danger of immediate loss varies from place to place. Special concern has been expressed for West Pakistan and some Arab communities in the Near East. Significant erosion is expected in the near future in Sudan, Ethiopia, and parts of West Africa.

The extensive collection of maize germ plasm resulting from efforts made in the 1950's will be surveyed and evaluated by a committee of experts engaged in maize research. Attempts will be made to determine the parts of the world where additional collecting is needed to ensure preservation of existing strains and populations. Maintenance and distribution of germ plasm will be studied in an effort to find areas in which improvements are needed.

Efforts are under way to bring into existing germ plasm banks the extensive but scattered collections that have been made in Europe during the past decade.

Data on numerous characteristics of 4,829 bean introductions have been stored in an automatic data retrieval system developed at the Taximetrics Laboratory on the campus of the University of Colorado, Boulder. The bean records include data on 26 plant characteristics and family, genus, species, and genetic information identifying a species hybrid. They also include information on origin (country and locality) and on the local variety name. Requests for material by characteristic can be processed within a minute. Answers to the queries appear on a printout. The cost of each request to the information bank is likely to be less than the cost of typing a letter.

The longitude and latitude of the collection sites for most of the *Phascolus vulgaris* accessions from Turkey have been determined. A plotter was used, with a computer map of Turkey, to show the geographic distribution of the sites. A computer program is being worked out whereby beans having a particular characteristic or combination of characteristics can be plotted as to origin. This type of study can be applied to records on collections from any part of the world.

The data on the beans from Turkey are especially significant even though most of the stocks were collected at bazaars. Dr. and Mrs. Basri Devecioglu, of Izmir, Turkey, who located the sites, stated that a bazaar could be expected to have beans grown primarily in a nearby area. As the information on disease reaction and other aspects of the collection is accumulated, this work may serve as a basis for a better understanding of the ecological and sociological factors that affect the culture of plant varieties.

The Rockefeller Foundation and ARS are cooperating in a pulse increase program, using working collections of beans, pigeon peas, chick peas, mung beans, and other types that are common in the diets of developing countries. The increase is designed to build up working stocks for preliminary evaluation and subsequent use in breeding programs. More than 20,000 collections are involved. Work is being done at the Federal Experiment Station, Puerto Rico, and in Colombia and Nigeria.

The Crop Ecology and Genetic Resources Branch, FAO, has initiated an international survey of holders of crop germ plasm. In the United States, reports for the Plant Science Research Division have been assembled by the Program Director. The reports show that commodity branches of the Crops Research Division hold an estimated 113,000 lines as seed in working collections with an additional reserve in the National Seed Storage Laboratory of 78,000 accessions. Similar information from holders of germ plasm in experiment stations was assembled by J. R. Harlan for FAO.

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APPENDIX B: PARTICIPANTS

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Conservation of Ecosystems

Along with increased public interest in environmental quality has come a desire to set aside and protect samples of natural environments. The major thrust has been directed toward preserving areas that have aesthetic or recreational value. Interest in areas having scientific value has been secondary.

Individual citizens, groups of citizens, and government agencies (federal, state, and local) have devoted a great deal of effort to acquiring natural areas, but they have often depended on inadequate criteria in determining the quality of the areas. They sometimes have had little idea of the value of areas already acquired, and often have not developed sound plans for managing the areas.

No one really knows how many natural areas have been set aside in the United States, what kinds of areas they are, what additional kinds of areas should be set aside in order to have a complete series of environmental systems, or what kinds of areas are still available for preservation. The great need is for more effective coordination and greater insistence on applying sound criteria to evaluate the research values of the areas.

Areas preserved for long-term scientific use provide natural outdoor laboratories for analyzing many kinds of ecosystems. The environment in these natural or seminatural areas can be compared with more disturbed environments and thus can serve as a means of measuring changes in environmental quality. The areas also provide opportunities for conducting research on the use, protection, and management of comparable terrestrial or aquatic areas. Data thus obtained are valuable as a basis for guides to resource management, such as land capability classifications. Many such areas are the source of animals and plants used in medical or agricultural experiments. (See "Conservation of Plant Genetic Materials," p. 89.) Finally, these areas may be the last protected habitats of endangered animal or plant species.

The conservation-of-ecosystems program is concerned with all kinds of ecosystems. In some ecosystems, man is the dominant environmental factor; in others, he is less important; in still others, he is essentially an intruder.

The Program Director is G. Sprugel, Jr.

OBJECTIVES

The chief objective of this program is to describe and preserve a variety of environments, both terrestrial and aquatic, for scientific purposes. The program will include disturbed areas, natural areas, and areas that have a long history of scientific study.

There are three immediate goals:

- To prepare an inventory of environments that have been set aside for research purposes and to identify other areas that should be set aside in order to ensure the protection of a complete, representative series of major ecosystems
- To develop management practices for preserving areas that have been set aside
- To establish a clearinghouse procedure by which information concerning research natural areas in the United States can be made readily available to scientists

RESEARCH METHODS AND PROGRESS

FEDERAL LANDS

A Federal Committee on Research Natural Areas representing the Forest Service, the Bureau of Land Management, the National Park Service, the Bureau of Sport Fisheries and Wildlife, the Department of Defense, and the Atomic Energy Commission was organized early in 1966 to inventory certain protected natural areas on federal lands—those having special research values—and to compile a directory of these areas. The federal government holds title to slightly more than one third of the land in the United States, most of its holdings being in the West and in Alaska. Federal lands are administered by a number of agencies for a variety of purposes. Most of the biotic, geologic, pedologic, and aquatic types of this country occur on these lands and present almost unlimited potential for natural science research.

The Committee was unable to find a system of classification that satisfactorily characterized the scientific features that the natural areas had been established to preserve. Thus, it became necessary for the Committee to accept a composite of several systems.

When the initial inventory was begun, few of the agencies had progressed far in identifying and setting aside research natural areas for special treatment. Utilizing existing data, the Committee published *A Directory of Research Natural Areas on Federal Lands of the United States of America* in the fall of 1968. The Directory (available from the U.S. Government Printing Office)

identifies, classifies, and briefly describes 336 areas representing examples of forest, range, and aquatic communities and geological features that had been set aside for scientific and educational purposes.

The Committee has been reorganized and enlarged under the leadership of R. E. Buckman, U.S. Forest Service, and has expanded its efforts to identify additional research natural areas worthy of preservation.

An effort is being made to locate and set aside some 325 additional areas to ensure the protection of ecosystems inadequately represented among the existing preserved sites.

Checksheets will be used in gathering more detailed information on the federal areas. Information thus obtained will be more comprehensive than that given in the Directory.

NONFEDERAL LANDS

The most difficult part of the conservation-of-ecosystems program is the inventory of terrestrial research natural areas on nonfederal public lands and on privately owned lands. During the summer of 1968, the Conservation Foundation assisted in this task by employing M. J. Pontrelli, University of Nevada, to assess the scope of the undertaking and to identify sources of information. Dr. Pontrelli prepared a report that gives, for many states, some sources from which information on nonfederal terrestrial research natural areas can be obtained. The report reveals that there is no central source of such information in 27 states. However, much of the needed information can probably be obtained from organizations and individuals in these states.

Paul Lemon, formerly of the State University of New York at Albany, has been employed to complete the task with funds that became available in the fall of 1970.

AQUATIC AREAS

In 1966, R. M. Darnell, Department of Oceanography, Texas A & M University, undertook the task of developing a program for identifying, describing, and cataloging freshwater areas in the United States that have scientific value. Plans for conducting a survey of freshwater sites were made, and scientists in various parts of the country were invited to participate. G. E. Likens, Cornell University, headed a team that made a detailed survey of freshwater sites in the Northeast. Some 75 freshwater sites in 22 states have already been recommended to the IBP for international recognition as aquatic natural areas. Checksheets have been completed on four sites.

MARINE AND ESTUARINE AREAS

J. E. Randall, Bernice P. Bishop Museum, Honolulu, is responsible for compiling a catalog of marine and estuarine areas of scientific interest. He has begun to develop criteria for selecting the areas and to bring together the available information on U.S. marine sites.* Seventy-six marine sanctuaries established under state laws have been identified in 13 states and 1 territory. Eighty-seven more have been proposed, and others are being studied. An additional 17 marine or estuarine sanctuaries have been proposed in states and territories where none have been established to date. Seventeen federal marine sanctuaries have been identified.

WORLDWIDE INVENTORY

A worldwide inventory of natural preserves is being compiled under the supervision of the Conservation Terrestrial Section of the International Biological Program. The objective is to describe the ecological characteristics and the special biological or conservation features of each area. Checksheets are used to collect the information.

Checksheets have been distributed to federal agencies and other responsible organizations for completion. The agencies are providing information on research natural areas and on some wilderness areas that are included in the inventory of U.S. federal lands (see "Federal Lands," above). About 200 checksheets have been completed and forwarded to IBP's Monk's Wood Data Center.

APPENDIX: PARTICIPANTS

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*J. E. Randall. 1969. Conservation in the sea; a survey of marine areas. Oryx 10:1.

HUMAN ADAPTABILITY COMPONENT

Biosocial Adaptation of Migrant and Urban Populations

The importance of studying migrants from rural to urban areas is emphasized by the extraordinary changes in the distribution of populations throughout the world. These changes are being forced by rapid social, political, and economic developments. Under the pressure of new technologies and rising expectations, the pace of change is accelerating, and rural or isolated peoples are transformed overnight into urban dwellers. Primitive tribes are brought into shattering contact with modern civilization.

Megalopolis expands at the expense of the countryside. The growth of suburbs has its counterpart in the desertion of rural villages and the return of farmland to woods. Shifts in population, no less notable in the developing than in the industrialized countries, are altering established ecological balances and subjecting increasingly larger groups to the stresses of migration and assimilation.

Important migrations are occurring throughout the world, but they have been subjected to little sophisticated analysis. In particular, the biological and psychological aspects have been ignored. Many writers have remarked upon the success of the overseas Chinese, the overseas Indians, and the Japanese-Americans. In contrast is the distress of blacks in metropolitan ghettoes and of southern whites in Cleveland and Cincinnati. In Latin America and Asia, villages lose many of their youth to the *barriados*, or urban slums.

Migration causes dramatic changes in the composition of local populations. There are counties in the United States where more than 70 percent of the persons who were 10–14 years of age in 1950 had left by 1960; many left as soon as they finished high school or dropped out. In some counties there are more people aged 70–79 than there are aged 20–29, and in at least 300 counties there have been years in which there have been more deaths than births. The United States is not the only country in which the cities grow at the expense of the rural areas. In Argentina, for example, there are villages from which more than half of the youths migrate.

There has been a vast, worldwide movement of populations from rural to urban areas, and the rate of urbanization is increasing. Peoples who have not shared fully in such movements in the past—American Negroes, Eskimos, Yugoslavian mountaineers, Russian peasants, Chinese villagers—are being swept into an industrialized, impersonal society with little preparation for such a different life. On the whole, the economic rewards have been considerable, but the social costs have been great. Important matters of public policy and of scientific concern are involved. Should the process of urbanization be accelerated or retarded? How can the stresses of assimilation in new communities be reduced? What is the effect upon a village of losing its youth? Does the city rob the countryside of the most innovative? What are the limits of human ability to adapt to new environments, and to what degree are these determined by genetic makeup, by biological constitution, by psychological set, by age, and by education? These are some of the questions with which this program is concerned. Others are posed in the statement of objectives that follows.

The Program Director is Everett S. Lee.

OBJECTIVES

The objectives of this program are to find the answers to the following questions:

- How do migrants differ from nonmigrants in the area of origin? From nonmigrants in the area of destination? From migrants in other migration streams? From migrants of earlier times?
- What is the impact of migration on the structure of the population at origin? On the structure of the population at destination? On the social and psychological milieu at origin and destination?
- What is the impact of migration on the psychological and physical state of the migrants? On the psychological and physical state of the migrants' children?
- What changes in social and economic conditions

have the greatest effect on the volume of migration? On the selection of prospective migrants? On the types of migrants' origins and destinations?

- What are the most important factors in the assimilation of migrants at destination?
- What are the most important obstacles to the assimilation of migrants?

RESEARCH PLANS

Research is planned that will highlight differences in response to environmental changes in different cultures and clarify differences in mobility among different types of people in the same culture. Special emphasis is placed on studies of groups in extreme or rapidly changing environments–for example, the Eskimo, the rain forest native, or the peasant in a society that is industrializing. The selection of migrants at origin and their assimilation at destination will be the focus of several studies.

Special attention will be paid to biological or health factors. It is well known that social and psychological factors are important in migration and urbanization, but little is known about physiological state or intellectual capacity as determinants of migration. Experiments will be made to see if genetic markers can be used to differentiate migrant from nonmigrant, and residual populations in areas of high out-migration will be examined for possible high incidences of physical or mental defects, some of which may be genetic in origin.

RESEARCH METHODS AND PROGRESS

STUDIES UNDER WAY

The following studies are under way: migrants from Holmes County, Mississippi; migrants from Yazoo County, Mississippi; and adjustment of peasants to industrial life (Yugoslavia).

Migrants from Holmes County

This study was originally designed in part as a segment of the IBP's study of migrant peoples. Data from a complete sample of the black population of Holmes County will be studied to assess the effects of migration on the health of rural Negroes who move from Holmes County to Chicago. Detailed questionnaires on family size and structure, education, occupation, income, type of house, dwelling area, religion, and social class will be completed for each available nonwhite family. Random samples drawn from this universe will be asked to participate in a health survey that will include height, weight, blood pressure, chest X ray, electrocardiogram, visual acuity, gross physical impairments, fat pad thickness, breast examination, hemoglobin, hematocrit, tests for sickle cell, and indications of malnutrition.

It is expected that about 750 migrants will be followed by the University of Illinois College of Medicine. Success or failure in Chicago will be assessed. It is hypothesized that successful migration and adjustment in Chicago will be associated with:

- A hill rather than a delta origin (nonplantation rather than plantation)
- Above-average education of parents
- Active religious participation by the family
- Presence of both parents in the home until all offspring are at least 9 years of age
- Nonpossession of a criminal record by parents
- Migration as a family unit
- Successful relatives in Chicago

Migrants in Chicago will be followed over a 3-year period, and nonmigrants in Holmes County will be followed over several years.

This project is unusual in that the cooperation of the Holmes County residents has been obtained, and some Holmes County residents will participate in the investigation. The study is directed by anthropologists and medical people from the University of Illinois.

Migrants from Yazoo County

This study is concerned with the characteristics of migrants from Yazoo County, Mississippi, to Chicago and other cities. It is financed by the Office of Economic Opportunity. The reasons for migration and assimilation difficulties at destination are explored. Migrants are located and interviewed at destination, and special emphasis is placed on nutrition and dietary habits. This study and the Holmes County study give a picture of the black migrant from the rural South in northern cities, a picture more detailed than any previously obtained. Such studies are important because of the continuing exodus of young people from rural areas in the South to large cities outside the region.

Contact with large cities changes the outlook in the communities of origin. In Yazoo County, as in Holmes County, numerous migrants have returned from Chicago, and a high proportion of the black population has visited Chicago or has had visits from relatives who migrated there. Initial findings from both studies suggest that migrants to Chicago from these poor Mississippi counties are more successful and less likely to be on welfare than are blacks raised in Chicago ghettoes.

Adjustment of Peasants to Industrial Life

This study is sponsored by the Federal Institute of Public Health, Yugoslavia, and by the National Center for Health Statistics, U.S. Public Health Service. It was initiated by Mitomir Savičević and Momčilo Kilibarda (see Appendix, p. 97).

The locale of the study is Montenegro, where there is an unusually good opportunity to study the adjustment of peasants to city life and industrial pursuits. In the last few years the one-time Turkish garrison town of Berena has been transformed into the industrial city of Ivangrad, where a large paper and cellulose mill, a plywood and plywood products factory, a leather factory, and a coal mine furnish employment for about 2,000 workers, most of whom were drawn directly from peasant life. The transition in many cases was abrupt, from sheep herding one day to work in the factory the next, from life in a mountain hut to an apartment in a modern high-rise building, from providing nearly all of one's food to buying food in a supermarket.

All of the 2,000 factory workers have been given a series of psychological, physical, and mental examinations, and all have been given 2-hour interviews in their homes. The interview was structured to give a complete picture of the worker's childhood and family background, together with many items designed to show attitudes toward country and city life and feelings of pessimism and optimism. Religion of parents, income, housing, smoking habits, drinking habits, amusement patterns, friends, family relations, and other items of demographic or socioeconomic importance were also included.

Psychologists gave an intelligence test, the Cornell Medical Inventory, and the Maudsley Personality Test to each worker. These tests were followed by a complete physical examination and a psychiatric examination. A full psychological, medical, and psychiatric report was filed for each person.

The same interviews and examinations were given to an equal number of controls selected in the villages from which the workers had migrated. Testing and examinations for both workers and controls were first administered in 1966, and the procedure was repeated exactly in 1967 and 1968 for all the workers. At the end of 5 years the workers and the control group will be examined again. Changes in physical and mental condition will be noted.

This is the largest study of its kind ever conducted and perhaps the best designed. Nearly all the persons in the sample were interviewed and tested. A monograph on the first results of the study is being prepared. These results indicate a high degree of selection at origin for the most intelligent, the healthiest, and the most optimistic among the persons electing factory work. They also have less indication of marked or incipient mental disorder.

An industrial medicine team remains in Ivangrad throughout the year and collects information on each worker's ability to meet quotas and get along with other workers, his supervisors, and townsmen. The records maintained by the factory management are made available for each worker.

FUTURE STUDIES

The following studies will be proposed for funding: cohort of 1948 (Sweden), assimilation of immigrants from different countries and the adjustment of their children (Israel), assimilation of native peoples in cities (Alaska), and migration of Appalachian whites to midwestern cities.

Cohort of 1948

This study is planned as a continuation of Thorsten Husen and Ejnun Neymark's study of migrants and nonmigrants in Sweden. Their study was concerned with the entire cohort of males born in Sweden in 1928 and called up for possible conscription in 1948.

Records on a 10 percent sample of the 1948 cohort have been kept. They include records from place of birth, records from schools, and employment records extending to 1956. In the IBP study, each of the men in the 1948 cohort who is still living will be located in the population registers for 1970. The Swedish system of maintaining population registers makes it possible to trace each living person who is still in Sweden and obtain much information about him.

Reports, including a book published by Neymark, indicated that intelligence is a highly significant factor in migration and that the higher the intelligence level the greater the rate of migration and the longer the distance of migration. Rural communities lose about 90 percent of their more intelligent males and retain a high proportion of the less intelligent. Furthermore, the less intelligent tend to migrate from large cities to smaller cities or from small towns to rural areas. Similar conclusions hold for socioeconomic background. It is evident that migrants have been far more successful than nonmigrants.

The work now planned would include following the 1948 cohort to 1970 and would stress the health of migrants and nonmigrants. The differentials that were shown to exist in 1956 will be reexamined. Many health data are available that have never been fully explored, and migration will be related to several indices of physical and mental health.

Assimilation of Immigrants from Different Countries

Population registers in Israel permit following persons'

activities in much the same way as in Sweden. In addition there are important records that were filed in connection with immigration and naturalization. Jews from different countries have had very different degrees of success in assimilating in Israel, and the children of some groups, particularly those from Asia and North Africa, have had some of the same difficulties in school and in regard to intelligence testing that have been experienced by American blacks. The Central Bureau of Statistics has proposed a study of the assimilation of migrants in which a number of socioeconomic indicators would be used to show the degree of assimilation. Fertility and health records of various kinds would also be considered. School records would be used to study the adjustment of children, and children raised in the *kibbutzim* would be compared with those who live with non-European Jews in the usual family situations.

Assimilation of Native Peoples in Cities

Alaska is still in a frontier stage, and the effects of intruding western culture into native cultures can be examined in areas undergoing rapid change.

The Institute of Social, Economic, and Governmental Research, University of Alaska, proposes a study of the assimilation of migrants from Eskimo and other native villages to Anchorage or Fairbanks. Native villages have long been under stress as a result of large numbers of young people abandoning traditional pursuits and taking various kinds of jobs in industry or entering the armed forces. A considerable number of girls have learned secretarial and clerical skills and have migrated to the larger towns or cities. At the same time, infant mortality has decreased sharply, so that the villages have high proportions of children and older people.

It is intended to locate the migrants from the villages and interview a large sample. School records of the migrants will be compared with those of their children. Anthropologists will make studies of villages that have been most affected by out-migration. Special attention will be paid to villages that are likely to be affected by drilling for oil.

Migration of Appalachian Whites

A number of scholars have proposed studies of the migration of Appalachian whites to midwestern cities. The University of Kentucky has files that trace the migrants from some communities over a period of several years. It is evident that migrants to the cities can be located and interviewed, and that they can be compared with the nonmigrants in regard to many characteristics. Reasons for migrating or not migrating can be obtained. Information concerning those who went to the cities but returned to their mountain homes will be sought.

An effort will be made to coordinate the several proposals and to see that the materials already collected are quickly exploited.

Migrants to and from Aberdeen, Scotland

This study will use the records maintained by Raymond Illsley and the faculty of the Medical School, University of Aberdeen. Records have been maintained on everyone hospitalized in Aberdeen during the last two decades. Records are also maintained on all persons born in Aberdeen hospitals. They have created a register that permits the comparison of migrants with the nonmigrant population. Persons migrating to Aberdeen can be compared with those who left Aberdeen. The population in the register is now over 20,000. These data show that migrant women are larger and heavier, have higher IQ's, and have less difficulty in childbirth than nonmigrant women, and the children of migrant women do better in school than the children of nonmigrant women.

The work now planned would extend the present comparisons of migrants and nonmigrants and introduce better controls for social status and length of residence in Aberdeen.

APPENDIX: PARTICIPANTS

Everett S. Lee, Department of Sociology, University of Georgia, Athens (Program Director; Yugoslavian study)
James Brown, Department of Sociology, University of Kentucky, Lexington (Appalachian study)
Charles Cannell, Field Director, Michigan Survey Center, University of Michigan, Ann Arbor (Yugoslavian study)
Thorsten Husen, University of Stockholm, Stockholm, Sweden (Swedish study)
Raymond Illsley, Department of Sociology, University of Aberdeen, Aberdeen, Scotland (Aberdeen study)
Momčilo Kilibarda, Chief, Section of Psychiatry, Federal Institute of Public Health, Belgrade, Yugoslavia (Yugoslavian study)
Henry Lorenzi, Milton-Olive III Memorial Program for Children, Lexington, Miss. (Holmes County study)
Bernice Montgomery, Milton-Olive III Memorial Program for Children, Lexington, Miss. (Holmes County study)
Ejnun Neymark, University of Stockholm, Stockholm, Sweden (Swedish study)
Daniel O. Price, Department of Sociology, University of Texas, Austin (Yazoo County study)
O. K. Sagen, Assistant Director, National Center for Health Statistics, U.S. Public Health Service, Washington, D.C. (Yugoslavian study)
Mitomir Savičević, Director, Institute of Industrial Medicine, University of Belgrade, Belgrade, Yugoslavia (Yugoslavian study)
Demitri B. Shimkin, Professor of Anthropology and Geography, University of Illinois, Urbana (Holmes County study)
Moshe Sichron, Central Bureau of Statistics, Jerusalem, Israel (Israeli study)

Nutritional Adaptation to the Environment

Nutritional studies in the U.S. program are integrated on a national and international basis with other studies of human adaptation. The results will assist mankind in making adjustments to present and future circumstances in relation to food. The records of anthropology and history and the contemporary world scene all show clearly that man's relative success in obtaining and consuming food that permits a close approach to optimum health is a major factor in efforts to survive and to advance socially and economically.

Experience in arctic, tropical, and temperate areas has resulted in three extreme ranges of food practices that are in sharp contrast in regard to critical margins of success or failure in human adaptability. In circumpolar areas, animals often are the only source of food. Because of this restriction, diets are monotonous and close to the limit of physiological tolerance in their high content of protein and fat and their low content of vitamin C. In tropical areas the reverse is true. Diets there tend to be derived directly from plant sources; they tend to be extremely low in good-quality protein and excessively high in starch or sugar; they are often low in total energy, minerals, and vitamin A. Temperate areas usually permit more varied and more abundant food production and generally a more favorable economic environment.

A major penalty on public health in all climates results from excessive caloric intake, which begins in early childhood and increases with advancing age. The problem of excessive caloric intake is especially severe in more economically advanced countries. The regulating factors involved should be identified very early in life so that a basis for effective adaptation and health conservation can be established. Temperate areas also include populations that contend with stresses of altitude, semidesert conditions, migration, and marginal soil deficiencies. Hence, surveys in addition to basic research are an important feature of many international studies.

Research to establish the nature and practical limits of human adaptability and to improve food resources accordingly will require recognition of genetic variability and carefully controlled studies with experimental animals to supplement research with human subjects.

A special feature of nutritional stress and adaptation is found in a worldwide trend of migration from rural areas into congested urban areas where cultural patterns are confusing and directions of improvements are not well established.

OBJECTIVE

The objective of this program is to guide mankind toward successful adaptation to environmental changes that relate to food.

RESEARCH PLANS

The program has three subprograms, each of which is related to an area of the world: tropical and subtropical ecology, temperate ecology, and arctic ecology. Each subprogram is coordinated with human population studies that are in progress in each of the areas.

The program also includes projects designed to sharpen the tools with which practical corrective measures can be evaluated, guided, and accelerated.

C. Glen King, Institute of Nutrition Sciences, Columbia University Medical Center, New York, New York, is Program Director. O. Lee Kline, American Institute of Nutrition, Bethesda, Maryland, is Coordinator.

Support for the management of this program is provided by the Agricultural Research Service, U.S. Department of Agriculture.

RESEARCH METHODS AND PROGRESS

TROPICAL AND SUBTROPICAL ECOLOGY

Developing countries in tropical climates are subject to a lack of protein that is expressed in the frequent oc-

currence of the disease kwashiorkor. Protein calorie malnutrition affects a large segment of the populations in the tropics. It is a serious problem in Latin America and in large sections of Africa, the Middle East, Southeast Asia, and Pakistan.

The following projects contribute to our knowledge of ways in which the nutritional status of people in the tropics can be improved by the identification and treatment of protein deficiency, nutritional anemia and infections related to undernutrition.

Development of Food from Cellulosic Wastes

A pilot plant has been constructed in which cellulosic wastes are converted to microbial proteins. This process includes a delignification step in which a mild caustic is used. The fermentation that follows uses a mixed culture of cellulomonas and alcaligenes. Cellulomonas is a species of cellulolytic organism not previously isolated.

Preliminary studies indicate that this material is nontoxic when fed to rats at a level of 40 percent of the diet. They also indicate that the product, which contains 70 percent of protein by amino acid analysis, supports a good rate of growth in rats. Methionine is the limiting amino acid.

Research continues to simplify the process and lower production costs. Mutations of the organism are being developed to provide more balanced amino acid composition of the protein.

The protein will be assessed for acceptability as human food and for feed and food uses.

Investigators: C. D. Callihan, W. H. Daly, Y. W. Han, C. E. Dunlap, V. R. Srinivasan, and W. F. McKnight, Louisiana State University, Baton Rouge, La. 70803

The following publications resulted from this work:

Callihan, C. D. 1970. How engineers are putting microbes to work. Chem. Eng. 77:160-164.

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Han, Y. W., and V. R. Srinivasan. 1969. Purification and characterization of *B-Glucosidase* from *Alcaligenes*. J. Bacteriol. 100:1355-1370.

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Development of Soy-Based Foods of High Nutritive Value

Soybeans are an important source of protein. Careful processing is needed to obtain a product acceptable for human consumption.

Soybeans are normally prepared by soaking in water before the grinding operation. The soaking continues over a period of several hours. Enzyme activity during this period results in products that cause off-flavors to develop. One product is 1-octen-3-ol, which has a mushroomlike odor. This product is reduced by use of water temperatures over 50° C, but yields of solids in the resulting milks are lowered. Extended studies on the flavor formation and the enzymic causes of flavors have led to a number of suggestions for improved processing.

The rancid flavor of soymilk as traditionally prepared resides in the volatile fraction. Wet-grinding the soaked beans at 80° C or higher prevents rancidity and results in a bland-tasting milk low in beany flavor.

The effectiveness of grinding procedures was determined by particle-size measurements consisting of a combination of wet-sieving and sedimentation tests. Hammer mills were as effective as attrition mills, and colloid mills were more effective. Colloid mills reduced the particle size to less than 0.05 micron.

The protein redispersibility of dried soymilks was increased by processing under conditions that split disulfide bonds and prevented sulfhydryl and hydrophobic interactions.

Nuts and legumes are roasted primarily to give them a desirable flavor and to change their texture. In the case of soybeans, roasting also improves nutritional quality by destroying antitrypsin.

Investigators: W. B. Robinson, L. R. Hackler, J. C. Moyer, K. H. Steinkraus, and J. P. Van Buren, Department of Food Science and Technology, New York State Agricultural Experiment Station, Cornell University, Geneva, N.Y. 14456.

M. C. Bourne, College of Agriculture, University of the Philippines, Laguna, Philippines

Effect of Undernutrition on Nucleic Acid and Protein Content of Developing Brain

Since the DNA content of diploid cells is constant, total organ DNA reflects the number of cells in that organ. Cell number is calculated by dividing total organ DNA by DNA per cell. The weight or protein content of each cell is determined by dividing the total organ weight by the number of cells.

This chemical approach was used in measuring the pattern of cellular growth in 31 human brains. These were brains of infants and of fetuses having a gestational

age of more than 13 weeks. Weight, protein, and RNA content increased linearly with time during these periods. Increase in DNA content leveled off at time of birth and reached a maximum at 8 to 10 months of age. This clearly indicates that cell division in the human brain continues to 8 to 10 months of age. Further growth is by increase in protein, RNA, and lipid content of each cell.

Following this the regional growth patterns in the human brain were determined. The data demonstrate that cell division is most rapid in the cerebrum postnatally. Cell division stops in the cerebrum, cerebellum, and brain stem at the same time (8 to 10 months).

In nine infants who died of severe malnutrition during the first year of life, there was a proportional reduction in weight and in protein, RNA, and DNA content of the brain. The number of cells was reduced, but weight per cell and protein content per cell were unchanged.

In a second group of marasmic children, it was demonstrated that the reduction in cell number occurred in all regions studied and that the most marked effects occurred in the cerebrum. In another study, lipid deposition was studied. Total cholesterol and phospholipid content in the brains of marasmic children was also found to be decreased.

These human studies reinforce a series of comparable studies that have been made on laboratory animals.

This demonstration that severe early malnutrition retards cell division and myelin synthesis in the human brain supports the growing concern over the possibility that malnutrition in early life retards mental development.

Investigators: Myron Winick and Irving Fish, Department of Pediatrics, Cornell Medical College, 1300 York Avenue, New York, N.Y. 10021
Julio Meneghello and Pedro Rosso, Department of Pediatrics, Hospital Roberto del Rio, Santiago, Chile

The following publications resulted from this work:

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Winick, M., and P. Rosso. 1969. The effect of severe early malnutrition on cellular growth of human brain. Pediat. Res. 31:898.
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Effects of Malnutrition in Early Life

Postnatal Nutrition and Adult Behavior toward Food A restriction in the quantity of food consumed by a rat in the first 3 weeks of life determines not only growth rate during that time but also subsequent growth characteristics when unlimited food is available. Studies have been made of food consumption and body composition in adult rats that have plateaued in body weight but differ in ultimate size because of nutritional restriction postnatally. The study includes a detailed examination of behavior toward food.

Beginning at parturition, female rats were fed a 12-percent protein diet during the nursing period (3 weeks). The pups at weaning were divided into two groups, one receiving a 5-percent protein diet that prevented weight gain in 4 weeks and the other receiving a restricted protein diet that prevented increase in body weight. After 4 weeks all animals were given a normal controlled diet ad libitum. At 6 months of age restricted rats were smaller than controls and consumed larger amounts of diet per unit of body weight. Results indicate that postnatal nutritional stunting of adult body size is not necessarily correlated with behavioral development. Behavioral abnormalities related to nutritional deprivations, however, are accompanied by a stunting of body size. Differences in eating habits were observed. The postnatally protein-restricted male animals exhibited significantly greater food spillage than the calorie-restricted or control groups. No difference in food consumption or food spillage was observed in female rats. The increased food spillage that was observed in the early malnourished groups of animals was seen only when the animals were made hungry. Hunger was induced by feeding them 1 hour per day. If food was provided ad libitum, no differences in food spillage were observed. Furthermore, this is not just a matter of calorie restriction but is due to calorie restriction (restricted milk intake during suckling) followed by a low protein diet for a period of at least 4 weeks. This combination of two forms of malnutrition (before and after weaning) gave by far the greatest effects on food behavior and food consumption.

Malnutrition and Exploratory Behavior of Rats In this study, which was in three phases, attention was given to the type of restriction and the time during which the restriction was imposed. In all three phases, a diet with a subnormal protein level was fed to rats in the preweaning period. In the first phase, the preweaning period was followed by severe protein restriction. In the second, the period was followed by severe calorie restriction. In the third phase, there was no restriction after the preweaning period.

After 4 weeks, the animals with protein- and calorie-restricted diets (those in the first two phases of the experiment) were rehabilitated with the basal diet. Protein restriction caused lower body weight and slower development of exploratory behavior, beginning with the 10th day of life. After weaning, severe protein or calorie restriction caused elevation of spontaneous activity. After nutritional rehabilitation, exploratory activity declined rapidly in the treatment groups. After 10 to 12 weeks, malnourished rats showed a low exploratory drive. Interpretation of a study such as this requires separate analysis of different characteristics of behavior.

Malnutrition in Avoidance Conditioning of Rats The study design described under "Malnutrition and Exploratory Behavior of Rats," above, was followed in this study. Rats were subjected to avoidance conditioning at 12 weeks of age. They learned to jump on a vertical screen when a conditioned stimulus was presented for 10 seconds, after which unconditioned stimuli (electrical shocks) were presented. Latent periods and spontaneous activity were recorded. There were no significant differences between control and previously malnourished rats in the learning rate expressed by the duration of latent periods, but striking behavioral disturbances developed in groups of rats that had been restricted both before and after weaning. Behavioral abnormalities were manifested as inadequate stereotyped movements and inability to delay or to extinguish the fixed conditioned reactions. Animals restricted both before and after weaning showed signs of disturbance; those restricted only in the preweaning period did not show signs of disturbance.

These studies demonstrate that the behavior of rats can be affected not only by changes in the nutritional state during the preweaning period but also by changes in the quantity or quality of the diet after weaning. A greater effect on behavior is exerted when restrictions are imposed both before and after weaning.

Investigator: Richard H. Barnes, Graduate School of Nutrition, Cornell University, Ithaca, N.Y. 14850

Endemic Goiter in Latin America

The widespread occurrence of endemic goiter in Ecuador and Peru has led us to examine causes of the condition and practical therapeutic measures that may be effective in improving iodine nutrition. The use of iodate as a food supplement has been effective. We continue to look for the effect of supplementation on the appearance of cretinism in the newborn, developmental milestones in the newborn, and the appearance of thyroid disease in the young as well as in more mature age groups. We are also attempting to relate general intelligence and performance to treatment in cases of goiter.

Iodized oil has been used as a prophylactic feature and has proved feasible without significant undesirable side effects and has been effective in preventing endemic goiter.

Investigators: John B. Stanbury, Department of Nutrition and Food Science, Massachusetts Institute of Technology, Cambridge, Mass. 02139
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Philip Dodge, Department of Pediatrics, Washington University School of Medicine, 500 South Kingshighway, St. Louis, Mo. 63110
Eduardo Pretell, Instituto de Investigaciones de la Altura, Departmento de Endocrinologia, Apartado 6083, Lima, Peru
Andries Querido, Dukzigt Hospital, Dr. Molewaterplein 41, Rotterdam, Holland

Evaluation of Fish Protein Concentrate

In Chile, as in most developing countries, one of the most serious sociomedical problems is chronic infant malnutrition, which retards development, growth, and psychological performance. Efforts to improve protein intake have been directed to utilization of fish protein concentrate in preschool children's food. This work has been done in a single site near Santiago. It will be extended to other areas.

Chemical composition, biological quality of the protein, and toxicity were determined for fish protein concentrate, sunflower presscake meal, and foods supplemented with these concentrates. Acceptability and tolerance were tested in human trials. The fish protein concentrate improved the biological quality of cereal-based foods and promoted normal growth in infants. Mixtures containing fish protein concentrate and sunflower presscake meal showed a high net protein utilization in the rat and produced normal growth in infants aged 1 to 5 months when they supplied 100 percent of the total daily dietary protein.

Continuing studies on other sources of protein involve detoxification of rapeseed meal for both animal and human consumption. In view of the ready supply of rapeseed, it is important to provide a rapeseed meal protein concentrate suitable for human use.

Investigators: C. O. Chichester, Department of Food Resource Chemistry, University of Rhode Island, Kingston, R.I. 02881
Fernando Monckenberg, Department of Pediatrics and Biochemistry, School of Medicine, University of Chile, Santiago, Chile

Food Composition Table for Use in East Asia

This project is sponsored by the Department of Health, Education, and Welfare and by the Food and Agriculture Organization.

The countries represented in the information on food composition are Burma, Thailand, Laos, South Vietnam, Cambodia, Malaysia, Singapore, Indonesia, Hong Kong, Philippines, Taiwan, Korea, and Japan. Data are being collected on the proximate composition and on minerals, vitamins, amino acids, fatty acids, and trace elements that have nutrient value. Information is accumulated through communication with key investigators, with libraries, and with other sources in the countries of interest. Food data are being tabulated in a format previously used for the African Food Composition Table, published in both English and French. It is hoped that any laboratory having accurate information on the composition of foods of East Asian countries will communicate such information to the principal investigators.

Investigators: W. T. Wu Leung, Nutrition Program, Health Services and Mental Health Administration, U.S. Department of Health, Education, and Welfare, 9650 Rockville Pike, Bethesda, Md. 20014
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Hair Root Morphology and Protein Synthesis in Disease

Changes in hair follicles are sensitive indicators of protein synthesis under conditions of protein inadequacy. Three types of studies have been conducted. They were concerned with (1) experimental protein deprivation and repletion of young adults in a metabolic ward, (2) grossly obese men who were being fasted for an 8-week period, and (3) children recovering from both forms of protein-calorie malnutrition in South America, and children with mild to moderate PCM in the Caribbean area.

In two separate studies, volunteers fed protein-free diets demonstrated significant hair root changes at the same time that urinary nitrogen levels had plateaued. Serum albumin and total serum protein values were normal at this time. When protein was added to the diet, the changes in hair roots reverted to normal. In children who have had either acute or chronic protein-calorie malnutrition, hair root recovery parallels closely the DNA-protein values from muscle biopsy samples. In the Caribbean studies of Negro preschool children, reduction in weight for age is accompanied by a reduction in hair root diameter. A study was conducted in Guatemala comparing eight parameters that have been suggested for the early recognition of malnutrition. The results of this study are being calculated.

Investigators: Robert B. Bradfield, Clinical Professor of Human Nutrition, Department of Nutritional Sciences, University of California, Berkeley, Calif. 94720
D. B. Jelliffe, Professor of Community Nutrition, University of the West Indies, Mona Post Office, Kingston, Jamaica

The following publications resulted from this work:

Bradfield, R. B. 1971. Protein deprivation: comparative response of hair roots, serum protein, and urinary nitrogen. Amer. J. Clin. Nutr. 24:405-410.
Bradfield, R. B., and M. A. Bailey. 1969. Hair root response to protein undernutrition. *In* Advances in biology of skin. IX. Hair growth. Proceedings of a symposium at University of Oregon Medical School, 1967. Pergamon Press, New York.
Bradfield, R. B., M. A. Bailey, and A. Cordano. 1968. Hair-root changes in Andean Indian children during marasmic kwashiorkor. Preliminary communication. Lancet, Nov. 30, 1968, p. 1169-1170.
Bradfield, R. B., M. A. Bailey, and S. Margen. 1967. Morphological changes in human scalp hair roots during deprivation of protein. Science 157:438-439.
Bradfield, R. B., A. Cordano, and G. G. Graham. 1969. Hair-root adaptation to marasmus in Andean Indian children. Lancet, Dec. 27, 1969, p. 1395-1397.
Bradfield, R. B., and E. F. P. Jelliffe. 1970. Early assessment of malnutrition. Nature 225:283-284.
Bradfield, R. B., E. F. P. Jelliffe, and J. Neill, Jr. 1970. A comparison of hair root morphology and arm circumference as field tests of protein-calorie malnutrition. J. Trop. Pediat. 16:195.
Bradfield, R. B., T. Yee, and J. M. Baertl. 1969. Hair zinc levels of Andean Indian children during protein-calorie malnutrition. Amer. J. Clin. Nutr. 22:1349-1353.

Improved Methods of Extracting and Utilizing Plant Proteins

Fermented foods are important components of diets in many parts of the world. A study of the value of fermentation in improving the nutritive value of food has been conducted. Fermentation does not generally improve the nutritive value of the protein but may increase vitamin content. Digestibility for humans of certain fermented foods (e.g., tempeh, ontjom, and bongkrek) is improved and the keeping quality is generally increased. Cooking time is often decreased. Organoleptic characteristics are generally improved. The wholesomeness of fermented foods is generally as good as or better than that of the ingredients from which they are produced. When aflatoxin-containing ingredients are used, there may be a hazard to health.

The effect of fermentation was studied to improve the efficiency of the process for extracting oil and protein from coconut meat. Coconuts available commercially vary widely in maturity and length of storage and in response to fermentation processing. Sixty percent of individual coconuts showed a breaking of emulsion with separation of oil and proteins when fermented under controlled conditions. Conditions of grinding and range of dilution were critical for rapid fermentation. The organism *Lactobacillus plantarum* was most effective in breaking the emulsion to yield a high grade, clear oil and with precipitated protein that was easily recovered in relatively undenatured form.

Investigators: Keith H. Steinkraus, L. Ross Hackler, and A. G. van Veen, New York State Agricultural Experiment Station, Cornell University, Geneva, N.Y. 14456

Increased Protein Supplies through Peanut Improvement

Cooperative research in the United States and in India indicates that the protein content of peanut seed could be increased by breeding. The average protein content of sound mature seed of a large number of diverse peanut genotypes from the two countries ranged from 23.6 to 30.5 percent when the genotypes were grown at Ludhiana, India, or at Tifton, Georgia. The possibility of increasing the protein content of seed by breeding appears more favorable for peanuts of the Virginia botanical type than for the Spanish type.

An obvious way to increase protein supplies is to use higher-yielding varieties. When 100 diverse genotypes from India and 100 diverse genotypes from the U.S. collection were grown at Ludhiana, India, from 1964 to 1966 in small-scale replicated tests, several Indian and U.S. genotypes substantially outyielded standard checks. The most promising of these have been included in larger-scale tests at Ludhiana. In general, the U.S. genotypes

that gave superior yields at Ludhiana show a high yield potential when grown in adapted areas in the United States.

In cooperative research with the Georgia and Oklahoma Agricultural Experiment Stations, three new productive Spanish peanuts of medium-sized seed were released to growers in 1969 and 1970. These are Spanhoma, a pure-line selection from Argentina; Tifspan, selected from progeny of a cross between Argentine and Spanish 18-38; and Spancross, selected from progeny of a cross between Argentine and the wild annual, decumbent species *Arachis monticola*. Argentine is a pure-line selection from Plant Introduction 121070, which was introduced into the United States from Argentina in 1938.

Little useful genetic resistance to pests has been found in cultivated peanuts. Certain related wild *Arachis* species are immune or highly resistant to several major pests, including Cercospora leafspots, peanut rosette, peanut stunt virus, and peanut rust. Wild *Arachis* species with such characteristics cannot be crossed successfully with cultivated peanuts. Cooperative research is in progress with the North Carolina and Oklahoma Agricultural Experiment Stations to correct this and make possible the incorporation of resistance or immunity to pests into improved commercial varieties. Such a development could result in enhanced production where there are pests for which no economic control is now available and could help sustain production levels if certain pesticides now used to control pests should become unavailable as a result of restrictions on their use or for other reasons.

Peanut genotypes with pods and seeds that resist invasion by *Aspergillus flavus* or *A. parasiticus* are being sought in cooperative research with the Alabama, Florida, and Georgia Agricultural Experiment Stations. Preliminary results indicate that seeds of certain genotypes are more resistant to invasion by *A. flavus* than others. If productive varieties with a high level of resistance to aflatoxin-producing molds can be developed, millions of tons of high-protein peanut cake or meal now unsuitable for food because of contamination by aflatoxins could be available for human consumption.

Exchange of peanut genotypes and production know-how is continuing with India and other countries. In the United States, research is continuing on the effect of genotype and production environment on the protein content of mature peanut seed. In our peanut variety improvement research, special emphasis is placed on increased yield potential, resistance to pests, and enhanced processing and nutritional quality.

Coordinator: W. K. Bailey, Plant Science Research Division, Agricultural Research Service, Beltsville, Md. 20705

The following publications resulted from this work:

Hammons, R. O. 1970. Spancross—a new peanut variety. Georgia Agr. Exp. Sta. Rep. 76.
Hammons, R. O. 1970. The Tifspan peanut variety. Georgia Agr. Exp. Sta. Rep. 77.

Influence of Specific Nutritional Deficiency on the Genetic Expression of Anemia

In 1968 the investigators studied the general problem of multihemoglobins within erythrocytes. Observations made during that study suggested the feasibility of studying the effect of iron and folate deficiency on relative synthetic rates of sickle and normal hemoglobins in patients with sickle-cell trait.

Later (1968–1969) the investigators and G. Milner studied the iron effect. Patients with sickle-cell trait were surveyed for relative proportions of Hb A and Hb S in their erythrocytes. Bone marrow samples for culture were taken from iron-deficient subjects showing disproportional amounts of the two hemoglobins. The disproportion was always in the direction of low Hb S. Iron was added to these marrow cultures to determine whether it would correct the disproportional synthesis. Since no consistent effect was noted, it is probable that iron deficiency affects synthesis at a less differentiated site than that tested in these studies. This work suggests certain aspects of biochemical genetics for future work.

Investigators: John F. Bertles, St. Luke's Hospital Center, Amsterdam Avenue at 114th Street, New York, N.Y. 10025
Paul F. A. Milner, Pathology Department, University of the West Indies, Kingston, Jamaica

Malnutrition in the Middle East

Studies on the requirement of human infants for folic acid have been completed on 10 subjects maintained for extended periods on a diet deficient in folic acid. Initial observations indicate that between 20 and 40 μg of folic acid daily approaches the amount necessary to meet the requirements of an infant for hemopoiesis. There is also evidence that frequently occurring deficiencies of folic acid, protein, and iron are causes of the anemia of kwashiorkor in Cairo.

A survey of the selenium and chromium content of 85 foods indigenous to the Middle East has been completed. The foods include pulses and seed, cereals and grains, vegetables, fruits, dairy products, meat, and eggs. In the Cairo area, selenium and chromium levels have been determined in plasma and erythrocytes of healthy children and of children with kwashiorkor. Values for selenium in the blood of adults have been obtained by activation analyses. Some of these values are lower than values reported in the United States. The selenium content of serum and erythrocytes of healthy children in

Cairo is significantly greater than that of children with protein-calorie malnutrition.

Investigations into ways of improving the ability of the Egyptian sandrat (*Psammomys obesus*) to survive in captivity have been successful, and metabolic studies are under way on this species.

Evidence pertaining to the epidemiology of xerophthalmia and hypovitaminosis A in the Middle East has been reported.

An interpretative monographic review on nutrition in the Middle East is being prepared for publication, and a second volume on the history and cultural role of food in the Middle East is near completion.

Investigator: William J. Darby, Division of Nutrition, Vanderbilt University, Nashville, Tenn. 37203

Multiple Etiology of Nutritional Anemias of Thailand

The first study of anemia and malnutrition in Chiang Mai, Thailand, has been completed. Its objective was to determine whether vitamin E has a unique role in the hemopoiesis of children with protein-calorie malnutrition.

Seventy-five children with protein-calorie malnutrition, 6 months to 4 years of age, were studied. The children displayed anemia with hemoglobin levels lower than 9.8 g per 100 ml. They were underweight and of less than expected height for age.

The most prominent vitamin deficiency was that of vitamin A. Thiamin and riboflavin deficiencies were the most obvious of the B-complex. Mortality rate declined from 25 percent the first 6 months to 4 percent the last 6 months principally as a result of a diagnostic and therapeutic attack on infections.

The children were divided into five groups. Groups I and IB were fed the house diet for treatment of protein-calorie malnutrition. This diet was adequate in protein and calories and in vitamins and minerals except for iron, tocopherol, and possibly folate. Groups II, III, and III_6 were fed a diet low in tocopherol but adequate in all other nutrients. Vitamin E was administered to Group I after 6 weeks, Group III after 3 weeks, and Group III_6 after 6 weeks.

Children in all groups grew comparably over the 6-week period, and serum proteins regenerated at the same rate in all groups.

Those in Groups I and IB had poor initial hemopoietic response and no increase in hemoglobin, owing to iron limitation. Administration of vitamin E after 6 weeks had no effect. Children in Groups II, III, and III_6 had a good initial hemopoietic response, with a reticulocytosis of 9 percent lasting 5 weeks and increased hemoglobin of 1.5 g per 100 ml. Administration of tocopherol to Groups III and III_6 elicited no response. Administration of iron to Group I at 6 weeks elicited a second reticulocyte response.

Children with protein-calorie malnutrition in northern Thailand present the classic syndromes of kwashiorkor and marasmus. The limiting nutrients for hemopoiesis appear to be protein and iron. The delayed reticulocyte response observed necessitates careful interpretation of the effect of any agent given as treatment. The results suggest that alpha-tocopherol is not a primary nutrient for hemopoiesis.

Investigators: Robert E. Olson, Donald Allen, Max N. Horwitt, Franz Simmersbach, Jo Ann Whitaker, Charles H. Tan, and David Morehead, St. Louis University School of Medicine, 1402 South Grand Boulevard, St. Louis, Mo. 63104

Mycotoxin Contamination of Food and Foodstuffs in Southeast Asia

Aflatoxins have been identified chemically in varying amounts and frequencies in market samples of many kinds of Thai foods. The commodity contaminated at highest levels and frequencies is peanuts. Other principal vectors of aflatoxins are corn and various legumes. Rice, the principal dietary staple, is rarely contaminated. Aflatoxin ingestion is being measured directly by dietary survey techniques in which plate samples of foods are analyzed and ingestion is calculated. Although aflatoxins are found in some instances, the level and frequency of exposure are much lower than market sample data had indicated.

Numerous samples of foods became highly toxic to rats when the endogenous molds were permitted to grow under laboratory conditions. About 50 isolates of various genera of molds were found to be toxin-producing when grown in natural substrates. Systematic attempts are being made to isolate and identify the toxic substances. It is not known whether these mycotoxins occur in human foods or whether they are important as hazards to public health.

The ingestion of aflatoxin and the incidence of primary liver cancer are being measured in two parts of Thailand in which the incidences of apparent liver cancer are very different. It is anticipated that these data will eventually permit a statistical evaluation of the possible relation between exposure to aflatoxin and incidence of liver cancer.

Aflatoxins (and possibly other mycotoxins) may be involved in the etiology of an acute toxicity syndrome in children.

Investigators: G. N. Wogan and R. C. Shank, Department of Nutrition and Food Science, Massachusetts Institute of Technology, Cambridge, Mass. 02139

C. M. Christensen, Department of Plant Pathology, University of Minnesota, Minneapolis, Minn. 55812
Natth Bhamarapravati, University of Medical Sciences, Bangkok, Thailand

Nutrition and Infections in India

In a study of nutrition and infections in India, illness and growth in children under 3 years of age living in Punjabi villages are being measured. The effects of complete medical care plus nutrition care, nutrition care alone, and medical care alone are being compared. In nutrition care, mothers are advised about weaning practices, and the use of supplements in feeding stations is confined to children who show a failure to grow by monthly weight measurements. Preliminary results show a synergistic effect of the combined complete medical care plus nutrition care as compared with medical care alone. Continued observation on the influence of nutrition care alone is necessary since our results so far are inconclusive.

Investigators: Carl E. Taylor and William A. Reinke, School of Hygiene and Public Health, The Johns Hopkins University, 615 North Wolfe Street, Baltimore, Md. 21205
Arnfried Kielmann (Field Director) and I. S. Uberoi, Narangwal Village Ludhiana District, Punjab, India
P. N. Wahi and V. Ramalingaswami, Indian Council of Medical Research, Ansari Nagar, Post Box 494, New Delhi, India

Nutrition Research in Thailand and Indonesia

In the northern and northeastern provinces of Thailand, a serious medical problem, especially in rural communities, is the frequent occurrence of bladder-stone disease in children. Biochemical examinations were given to village children and to urban children, and the results were compared. It was found that village children excreted significantly lower levels of inorganic phosphate and inorganic sulfate and that the incidence of oxalcrystalluria was much lower. Administration of methionine to village children resulted in increased urinary inorganic sulfate, whereas vitamin B_6 supplementation had no effect. These results indicate an inadequate intake of protein. In the bladder-stone cases (rural children), supplementation with inorganic orthophosphate resulted in an increase in urinary orthophosphate and pyrophosphate, and there was an associated reduction in urinary calcium and oxalate. Oxalcrystalluria was seen to disappear within 24 hours after supplementation. The conclusion was that in the Thai provinces bladder-stone disease results chiefly from diets that are low both in protein and in phosphate.

Human ecological studies have been conducted in 10 villages in northeastern Thailand. Emphasis was placed on nutritional status of children, dietary habits and patterns, and other aspects of living conditions. Information was collected by distributing questionnaires and by making visits during which preschool children were given complete medical examinations. The information revealed general poverty, low educational level on the part of the children, and varying degrees of malnutrition in each of the villages.

Although the financial support for this work, furnished by the National Institutes of Health, was terminated in 1969, Dr. Dradjat D. Prawiranegara in Indonesia and Dr. Aree Valyasevi in Thailand have been able to continue the study of communities with the assistance of volunteer workers. The workers, who live in the communities, are trained in the fundamentals of good ecological practice. Their contribution has led the Indonesian government to recognize the importance of volunteers. The government's new 5-year plan includes the use of some 70 volunteers in its community improvement effort.

Volunteers were engaged in a similar undertaking in East Java, Indonesia. The volunteers, most of whom were college graduates who had studied human ecology, were sent into a community in the city of Bozor. Each lived with a family and through this relationship was able to demonstrate to the community the value of improved living practices.

Principal investigators: Paul Gÿorgy, University of Pennsylvania, Philadelphia General Hospital, Philadelphia, Pa. 19104
Aree Valyasevi, Dean and Professor of Pediatrics, Ramathibodi Hospital, Bangkok, Thailand
Robert Van Reen, U.S. Naval Medical Research Institute, Bethesda, Md. 20014
Dradjat D. Prawiranegara, Professor of Nutrition, University of Indonesia, and Assistant Dean, School of Public Health, Jakarta, Indonesia

Nutritional Anemia in East Asia

Iron deficiency anemia is widespread throughout the world. In addition, megaloblastic anemia is a problem in world health. The latter may result from any defect in nucleoprotein synthesis, but in more than 95 percent of the cases it results from deficiency of folic acid or vitamin B_{12}. Folate deficiency appears to occur among many of the economically disadvantaged people of the world, especially pregnant women. A deficiency of vitamin B_{12} is common among vegetarians, patients with sprue, and the elderly. These studies indicate that folate and vitamin B_{12} deficiencies resulting in serious megaloblastic anemia occur widely and are of particular interest in East Asia.

The World Health Organization has initiated collaborative studies of these diseases. Reference centers for the studies have been established at St. Bartholomew's Hospital in London (under Professor David Mollin), at the Instituto Venezolano de Investigaciones Cientificas in Caracas (under Professor Miguel Layrisse), and at the University Hospital of the University of Malaya in Kuala Lumpur (under Professor Kam-Seng Lau and Dr. Herbert). This program is designed to help each country delineate the incidence, etiology, and treatment of nutritional anemia.

Studies are continuing to examine the possibility of an etiologic infectious agent in tropical sprue. This disease, in which anemia is a common finding, affects nearly 100 million people in East Asia.

Investigator: Victor Herbert, The Mount Sinai School of Medicine, 100th Street at Fifth Avenue, New York, N.Y. 10029

The following publication resulted from this work:

Herbert, V. 1968. Megaloblastic anemia as a problem in world health. Amer. J. Clin. Nutr. 21:1115-1120.

Nutritional Studies in Puerto Rico

A survey in the slum area of Juana Matos, Cataño, Puerto Rico, was conducted as part of a continuing program in Puerto Rico. The area is across the bay from San Juan. It had a population of 2,655, divided into 544 families. The survey included clinical examinations (1,796 persons), biochemical tests (910 persons), and collection of dietary data (59 families).

Annual income in half the families was $1,000 to $3,000 and the general educational level was low.

The diet was generally below the recommended allowances for calories, calcium, vitamin A, vitamin C, and riboflavin. The prevalence of observable nutritional deficiency was low. Retardation of growth, as expressed in height and weight for age, and considerable obesity among women were observed.

Hematologic findings showed a low incidence of hypochromic anemias or low plasma protein levels. Plasma ascorbic acid was adequate in all subjects. Urinary excretions of riboflavin and niacin indicated a substantial degree of deficiency. Intestinal infestation with helminth parasites was prevalent.

Investigators: Nelson A. Fernandez, Jose C. Burgos, and Conrado F. Asenjo, Department of Biochemistry and Nutrition, School of Medicine, University of Puerto Rico, San Juan, Puerto Rico 00905

The following publication resulted from this work:

Fernandez, N. A., J. C. Burgos, C. F. Asenjo, and I. R. Rosa. 1969. Nutrition survey of two rural Puerto Rican areas before and after a community improvement program. Amer. J. Clin. Nutr. 22:1639-1651.

Relationship of Diet to the Performance of the Combat Soldier

The marked incidence and severity of acute mountain sickness (AMS) resulting from abrupt altitude exposure is a major problem in maintaining maximal efficiency of troops, and could seriously impair military performance and operations. In past studies the severity of AMS symptoms were gradually increased, reaching their maximum at 36 hours of acute altitude exposure at 4,300 meters. In two later studies, the AMS were of short duration, reaching their maximum at 6-10 hours. In both of these later studies, the men were physically conditioned prior to altitude exposure and were consuming normal and high carbohydrate diets.

Anorexia has been reported in previous studies by our laboratory and has usually been accompanied by negative nitrogen and water balances. In one study, it was observed that, with some motivation, the daily food intake can be maintained after abrupt altitude exposure. Under these conditions, one observes positive nitrogen and mineral balances, greatly reduced body weight losses, normal blood electrolytes, and normal fasting glucose levels and glucose tolerance curves. It appears that many of the biochemical changes previously attributed to hypoxia at altitude may be partly due to anorexia and the subsequent caloric deficit.

Body hypohydration has been shown to occur at altitude during acute exposure. Although extracellular fluid is practically unchanged, total body water and intracellular waters are both significantly decreased. Other body fluid changes include a negative water balance, significantly decreased blood and plasma volumes, and a natural diuresis.

Heavy physical activity and physical conditioning prior to acute high-altitude exposure can greatly reduce the severity of acute mountain sickness (AMS). During acute altitude exposure, there appears to be a minimal carbohydrate requirement. One usually observes anorexia (25 to 40 percent decrease in food intake) during acute altitude exposure, and under these conditions the daily carbohydrate intake should be at least 320 g. It appears that body hypohydration and a naturally occurring cold diuresis are adaptive mechanisms for high-altitude exposure.

Investigators: C. Frank Consolazio, H. L. Johnson, H. J. Krzywicki, and T. A. Daws, U.S. Army Medical Research and Nutrition Laboratory, Fitzsimons General Hospital, Denver, Colo. 80240

The following publication resulted from this work:

Consolazio, C. F., L. O. Matoush, H. L. Johnson, H. J. Krzywicki, T. A. Daws, and G. J. Isaac. 1969. Effect of high carbohydrate diets in performance and clinical symptomatology after rapid ascent to high altitude. Fed. Proc. 28:937-943.

Role of Zinc Deficiency in Growth Retardation

This study was designed to determine whether zinc deficiency was the cause of pronounced growth retardation and delayed or absent sexual maturation in subjects from villages near Shinaz, Iran. Seventeen "dwarfs," all aged 19 or 20, who had been rejected by an Iranian Army induction center agreed to stay in the hospital for a year. They were divided into three groups. Group I received a well-balanced hospital diet containing ample animal protein. Group II received the same diet plus a capsule of zinc sulfate daily. Group III received the hospital diet for 6 months and the diet plus zinc sulfate for the next 6 months. Analysis of rate of growth and onset of sexual functioning revealed that the diet alone resulted in gradual growth and sexual maturation but that the addition of zinc sulfate resulted in greatly enhanced growth and development ($P < .001$).

It is concluded that zinc deficiency occurs in man and produces abnormalities similar to those seen in experimental zinc deficiency of animals.

The cause of this zinc depletion is thought to be the diet consumed by villagers, which consists largely of unleavened bread. This has a high content of phytate, which binds zinc, making it unavailable. The degree of this problem is being investigated in Iran. Various breads are being analyzed for phytate and the effect of fermentation on destroying phytate. Studies of zinc and nitrogen balance are being conducted in the metabolic ward of Nemazee Hospital. Seven of the first eight apparently healthy village adults were in strongly positive zinc balance, which indicates a deficient state. There was a tendency toward negative nitrogen balance, which suggests impairment of protein synthesis in the zinc-deficient state.

Investigators: James A. Halstead, Consultant in Clinical Nutrition, Trace Element Research Laboratory, Veterans Administration Hospital, Washington, D.C. 20422

John G. Reinhold, Director, Pahlavi Nutrition Research Project, Pahlavi University, Shinaz, Iran

James C. Smith, Jr., Chief, Trace Element Research Laboratory, Veterans Administration Hospital, Washington, D.C. 20422

TEMPERATE ECOLOGY

Good-quality protein foods are abundant in the United States, Canada, Western Europe, and other countries in the Temperate Zone. Nevertheless, research is needed to improve the food produced for our own people and for export. Genetic research to improve the protein quality and yield of cereal foods, and research on all other types of potential natural sources of protein, must continue.

Most of the nutrition research dealing with problems in the Temperate Zone is relevant to tropical countries also. However, the investigations described here relate primarily to local problems and, in general, are conducted in the United States.

Diet and Fat Metabolism

Although the carbohydrates have long been considered of nutritional importance, chiefly as a source of calories, there is increasing interest in the individual carbohydrates because of possible differences in their effect on lipid metabolism. Investigations on the influence of several types of dietary carbohydrate on lifespan and lipid metabolism have been conducted with two strains of experimental rats. Cholesterol and noncholesterol lipids were generally higher in livers of both strains when diets containing 25 percent of cooked egg and sucrose were fed than when the carbohydrate was dextrose or cornstarch. Carbohydrate differences were much more marked in a strain of rats developed in this laboratory (BHE) than in a strain of Wistar rats. Renal disease, the chief cause of death in the BHE rat, was accelerated by the diet containing sucrose. Degenerative changes in the kidney were rarely seen in the Wistar rat, and survival was not significantly influenced by type of diet. Studies with three other commonly used strains of rats, directed toward establishing the extent to which fructose may be contributing to the metabolic response observed with sucrose, have been completed but have not yet been evaluated.

Investigators: Mildred Adams and Duane Benton, Human Nutrition Research Division, Agricultural Research Service, Beltsville, Md. 20705

The following publications resulted from this work:

Durand, A. M. A., M. Fisher, and M. Adams. 1968. The influence of type of dietary carbohydrate: effect on histological findings in two strains of rats. Arch. Pathol. 85:318-324.

Lakshmanan, F. L., E. M. Schuster, and M. Adams. 1967. Effect of dietary carbohydrate on the serum protein

components of two strains of rats. J. Nutr. 93: 117-125.
Taylor, D. D., E. S. Conway, E. M. Schuster, and M. Adams. 1967. Influence of dietary carbohydrates on liver content and on serum lipids in relation to age and strain of rat. J. Nutr. 9:275-282.

Experimental Scurvy in Man

There is considerable difference of opinion regarding the amount of vitamin C necessary in the diet of normal adults. Some authorities believe that tissue saturation is beneficial whereas others believe that saturation is not necessary in the interest of health. The objectives of this project were to measure, by means of carbon 14 labeled l-ascorbic acid, the body pool of vitamin C and to study its rate of depletion during ascorbic acid deprivation.

Six healthy men were fed a diet devoid of vitamin C but adequate in all other nutrients. Mild scurvy developed in the third month of deprivation. Clinical symptoms of scurvy were present when the pool size of the vitamin had decreased to about 300 mg and the rate of catabolism of vitamin C was less than 9 mg daily.

Urinary excretion of ascorbic acid ceased by the 23rd day of deprivation and was again detected after the body pool of ascorbic acid was partly repleted. A daily intake of 6.5 mg was sufficient to cause slow disappearance of clinical signs of scurvy in one subject.

Despite the recorded rarity of ocular vascular lesions in human scurvy, conjunctival lesions appeared in five of nine subjects with induced scurvy. The lesions ranged from minute bulbar conjunctival hemorrhage to a large subconjunctival hemorrhage accompanied by palpebral petechial hemorrhages and intense congestion of the conjunctival vessels.

The data reported and data obtained in a subsequent study, the results of which have not yet been published, are in agreement with the results of the Medical Research Council Sheffield study, which indicated that a daily dose of 10 mg of ascorbic acid is sufficient to cure scurvy in man.* The results also suggest that 30 mg is an adequate daily allowance of ascorbic acid.

Investigator: Robert E. Hodges, Department of Internal Medicine, University Hospitals, University of Iowa, Iowa City, Iowa 52240

The following publications resulted from this work:

Baker, E. M., R. E. Hodges, and J. Hood. 1969. Metabolism of ascorbic-1-^{14}C acid in experimental human scurvy. Amer. J. Clin. Nutr. 22:549-558.

*Medical Research Council. 1953. Vitamin C requirement of human adults: a report by the Vitamin C Subcommittee of the Accessory Food Factors Committee. No. 280. Compiled by W. Bartley, H. A. Krebs, and J. R. P. O'Brien. Medical Research Council, London. 179 p.

Hodges, R. E., E. M. Baker, J. Hood, H. E. Sauberlich, and S. C. March. 1969. Experimental scurvy in man. Amer. J. Clin. Nutr. 22:535-548.
Hood, J., and R. E. Hodges. 1969. Ocular lesions in scurvy. Amer. J. Clin. Nutr. 22:559-567.

Human Iodine Requirements and Substances in Foods That Affect Thyroid Function

Although goiter has been found to occur generally in areas where iodine intake is low, in some areas a majority of the population show no clinical evidence of abnormal thyroid function in spite of subnormal levels and low iodine intakes. To study the possible mechanism involved, the distribution of iodoamino acids and iodoproteins in the thyroid glands of goats was investigated. Thyroids were obtained from goats from an endemic goiter area and from an area free from endemic goiter. Previous studies had shown that the thyroids of goats from an endemic goiter area had pathophysiological changes similar to those found in human thyroids from the same area. Thyroid glands of goats living in an area of severe environmental deficiency of iodine showed higher mono-iodotyrosine/di-iodotyrosine and tri-iodothyronine/thyroxine ratios than the glands of those living in an area of iodine abundance. There were also differences in the incorporation of ^{131}I in the iodoproteins of the thyroids.

The OZT (5-vinyl-1, 2-oxazolidine-thione), ITC (isethiocyanate), and TC (thiocyanate) content of seven vegetables has been determined and the effect of these substances on the thyroids of chickens and rabbits has been studied. The OZT was found to increase the I^{131} uptake by the thyroid. This was proportional to the increase in size and was not overcome by iodide. The ITC and TC compounds reduced the I^{131} uptake. Rapeseed meal had a high level of OZT and significant levels of ITC and TC, and it was active in thyroid enlargement. Cows fed rapeseed meal did not have OZT in the milk, but significant levels of TC were found. Milk from cows fed rapeseed meal did not produce a good quality of cheese. Some substances in the milk apparently interfered in the ripening of the cheese. The levels of goitrogens found in vegetables are not considered great enough to produce goiter in humans consuming normal amounts.

Investigators: Ruth Leverton, Mildred Adams, and Duane A. Benton, Human Nutrition Research Division, Agricultural Research Service, Beltsville, Md. 20705

Nutritional Status of Preschool Children in the United States

In view of reports of serious malnutrition among children in southern states, particularly Mississippi, we

undertook a survey of 585 preschool children in cooperation with the Mississippi State Board of Health and the University of Mississippi Medical Center. This was a pilot study in preparation for a larger national study. Data indicated some restriction of caloric intake of children in low-income families, and the calcium and ascorbic acid intakes appeared inadequate. Also, it was found that most of the children sampled were ingesting insufficient iron to meet their needs. Mild iron deficiency anemia appears to be common, particularly among poor children.

In 1968 children in two countries in southern Ohio were examined for nutritional adequacy. It was concluded that serious hunger of malnutrition is not widespread in those counties. A number of the children were smaller than average at the time of the study. Anemia occurred at 2.5 times the rate at which it occurs on a national scale. About one fifth of the preschool children had low levels of plasma ascorbic acid. Calcium intakes were low in a significant number. A more extensive evaluation of the hematological status in children indicates that iron deficiency is not an uncommon occurrence among preschool children in the United States. The incidence is probably greatest among poor children. It appears that a preschool child with anemia frequently is deficient in iron.

The field studies in this project have been completed but analysis of the data is yet to be published.

During the course of the population studies it was possible to refine the method for quantitating vitamin A in serum or plasma through the use of silicic acid column chromatography and fluorometry. A fluorescing interfering substance was identified, and a procedure for differentiating it from vitamin A was developed. Also incident to the large study was an attempt to identify phenotypes of serum cholinesterase. An automated method has been described that measures serum cholinesterase activity and identifies the usual and atypical forms of enzyme.

Investigator: George M. Owen, Department of Pediatrics, Children's Hospital, The Ohio State University, Columbus, Ohio 43205

The following publications resulted from this work:

Garry, P. J. 1971. A manual of an automated procedure for measuring serum cholinesterase activity and identifying enzyme variance. Differentiation by means of tris and phosphate buffers. Clin. Chem. 17:192.

Garry, P. J. 1971. Serum cholinesterase variants: examination of several differential inhibitors, salts, and buffers used to measure enzyme activity. Clin. Chem. 17:183.

Garry, P. J., J. D. Pollack, and G. M. Owen. 1970. Plasma vitamin A assay by fluorometry and use of a silicic acid column technique. Clin. Chem. 16:766.

Owen, G. M., P. J. Garry, K. M. Kram, C. E. Nelsen, and J. M. Montalvo. 1969. Nutritional status of Mississippi preschool children. Amer. J. Clin. Nutr. 22:1444-1458.

Owen, G. M., P. J. Garry, A. H. Lubin, and K. M. Kram. In press. Nutritional status of preschool children: plasma vitamin A. J. Pediat.

Owen, G. M., C. E. Nelsen, and P. J. Garry. In press. Nutritional status of preschool children: hemoglobin, hematocrit and plasma iron values. J. Pediat.

Owen, G. M., C. E. Nelsen, K. M. Kram, and P. J. Garry. 1969. Nutritional status of preschool children in two counties in southern Ohio. Ohio State Med. J. 65: 809-814.

Nutritional Value of Wheat and Wheat Products

Wheat makes up more than 80 percent of the cereal products consumed as food in the United States. A most comprehensive study in terms of numbers of nutrients determined and numbers of wheat products studied has been conducted to provide up-to-date information on the nutrient contributions of wheat and wheat products. Five hard wheats, four soft wheats, two durum wheats, and the flours milled from these wheats have been analyzed for four B vitamins, tocopherols, 15 fatty acids, 14 minerals, protein, and amino acids. The various forms of the vitamins were measured, and changes that occurred during milling and processing were determined.

Only 5 of the 15 fatty acids were present in significant amounts in the samples studied. Linolenic acid occurred in the largest amounts. Individual samples from all regions of the country had essentially the same fatty acid composition. About 10 percent of the tocopherols present in hard and soft wheats and 40 percent of those in durum wheat survived the milling and bleaching process. Of the total tocopherol content, two thirds was in the form of epsilon tocopherol and less than 10 percent was in the alpha form.

Major losses occurred in the B vitamins, thiamin, riboflavin, niacin, and vitamin B_6. Less than 20 percent remained after 60 percent extraction.

Changes in mineral content were significant. Less than 25 percent of the iron, phosphorus, potassium, copper, magnesium, manganese, nickel, and zinc were retained. As expected, the lower the percentage of the extraction, the lower the mineral content. This is important information in view of the essentiality of certain trace elements and the variable availability in foods.

Consumption of diets containing 3½ ounces of unenriched flour daily would provide the following fraction of the Recommended Daily Allowance: 10 percent for thiamin, 2 percent for riboflavin, 8 percent for niacin,

4 percent for vitamin B_6, 2 percent for calcium, less than 10 percent for iron, 10 percent for magnesium, and 16 percent for phosphorus.

Investigators: W. A. Gortner and E. W. Toepfer, Human Nutrition Research Division, Agricultural Research Service, Beltsville, Md. 20705

The following publications resulted from this work:

Eheart, J. F., and B. S. Mason. 1970. Nutrient composition of selected wheats and wheat products. V. Carbohydrate. Cereal Chem. 47:715-719.

Inkpen, J. A., and F. W. Quackenbush. 1969. Extractable and "inbound" fatty acids in wheat and wheat products. Cereal Chem. 46:580-587.

Polansky, M. M., and E. W. Toepfer. 1969. Nutrient composition of selected wheats and wheat products. IV. Vitamin B-6 components. Cereal Chem. 46: 664-674.

Slover, H. T., J. Lehmann, and R. J. Valis. 1969. Nutrient composition of selected wheats and wheat products. III. Tocopherols. Cereal Chem. 46:635-641.

Toepfer, E. W., E. M. Hewston, F. N. Hepburn, and J. H. Tulloss. 1969. Nutrient composition of selected wheats and wheat products. I. Description of samples. Cereal Chem. 46:560-567.

Zook, E. G., F. E. Greene, and E. R. Morris. 1970. Nutrient composition of selected wheats and wheat products. VI. Distribution of manganese, copper, nickel, zinc, magnesium, lead, tin, cadmium, chromium, and selenium as determined by atomic absorption spectroscopy and colorimetry. Cereal Chem. 47: 720-731.

Nutritive Factors in the Immunological Process

The significant role of vitamin B_6 in the development of immune processes in animals has been established by measuring change of serum antibodies in animals deficient in vitamin B_6. This is not unequivocal proof since the serum antibody level reflects an equilibrium between the rate of synthesis and release and the rate of destruction and excretion. There was a need to study the effect of vitamin deficiency on the individual discrete processes and on the metabolism of antigen before it reaches target tissue, such as the spleen.

Cellular antibody synthesis was determined by the Jerne agar-plaque technique in normal rats and in rats deficient in vitamin B_6. The decreased cellular immune response observed in the deficient animals was independent of the inanition and was restored to normal by administering pyridoxine shortly before immunization. Accumulation of antigen by the spleen was not impaired in the deficient animals.

The role of ascorbic acid in the mechanisms of antibody synthesis has long been a matter of dispute. It has been demonstrated that guinea pigs deficient in vitamin B_6 produce less circulating diphtheria toxoid antibody.

Severely scorbutic guinea pigs maintained on a highly purified deficient diet were immunized with diphtheria toxoid. No deleterious effects on primary or secondary circulating antibody formation were observed in these animals.

Studies are being continued on the possible role of pantothenic acid in the functioning of individual antibody-producing cells. This relates to a major interest in the role of pantothenic acid in protein synthesis and transport.

Investigator: A. E. Axelrod, Biochemistry Department, School of Medicine, University of Pittsburgh, Pittsburgh, Pa. 15213

The following publications resulted from this work:

Kumar, M., and A. E. Axelrod. 1968. Cellular antibody synthesis in vitamin B_6-deficient rats. J. Nutr. 96:53.

Kumar, M., and A. E. Axelrod. 1969. Circulating antibody formation in scorbutic guinea pigs. J. Nutr. 98:41.

Protein Value of Plant Foods

The problem of meeting protein requirements with plant proteins when high-quality animal proteins are not available or are not economically feasible is one of great concern. Current research is directed toward supplying information on selected aspects of this problem.

Diets low in protein or containing proteins of poor quality were found to be associated with a decrease in brain glutamic dehydrogenase and decarboxylase and an impairment in psychological performance of the rat. In contrast, mere caloric restriction prior to or after weaning had no such effect. The postweaning diet appeared to be more important than the maternal diet for development of offspring, but the latter did affect breeding performance, birth weight, and weaning weight. Dull and bright strains of rats have been developed by selective breeding over four generations, and learning ability is being evaluated by selected measurements of psychological performance.

Investigations are under way to add to our information on the possible supplementation of cereal diets deficient in lysine with legumes containing a high level of this amino acid. The purpose is to find a way to formulate low-cost meals for postweaning children. Preliminary evaluations of various food combinations are being made in growth studies of rats. A diet composed of cereal or millet with bengal gram and leafy vegetables

compared favorably with a 10 percent casein diet and was superior to a diet of bread enriched with vitamins, minerals, and lysine. Other combinations will be tested and the most promising ones will be fed to young children to determine their nutritional response to such diets.

Although there has been limited evidence suggesting that the protein efficiency ratio of tempeh, a fermented soybean product, is superior to that of the unfermented soybean, recent research has failed to confirm this finding. Protein efficiency ratios of freshly prepared or stored tempeh and of unfermented soybeans were not significantly different. Protein values of tempeh were improved when properly supplemented with lysine, methionine, and threonine. The antioxidant isolated from tempeh was found to be ineffective as a substitute for vitamin E.

Investigators: Ruth M. Leverton, Mildred Adams, June Kelsay, and E. W. Toepfer, Human Nutrition Research Division, Agricultural Research Service, Beltsville, Md. 20705

Relationship of Dietary Deficiency and Impairment of Mental and Somatic Development

With the aid of germfree and limited-flora animals, absolute levels of amino acids required for normal development, and the effect of intestinal microflora in changing those requirements, can be determined. Diet formulations, behavioral tests, and biochemical tests have been developed for determining interactions among early amino acid deficiencies, intestinal microflora activities, and later behavioral changes in rats. Amino acid balances in defined diets have been improved, and solid-type amino acid diets have been found adequate for reproduction in germfree animals. A series of behavioral tests measuring activity levels and learning capacity have been administered to young adult rats reared under germfree or conventional conditions. Differences between the behavioral responses of the two groups of rats were found in the initial studies, but the differences were reduced to nonsignificant values in later tests in which closer control of other environmental variables was achieved. Pancreatic and intestinal enzymes have been assayed to ensure that germfree animals fed defined diets have sufficiently normal levels to permit evaluation of the effects of amino acid deficiencies and microflora activities on these critical enzymes. Liver enzymes involved in intermediate carbohydrate metabolism have been studied to assess the extent of general microflora effects.

Investigators: Bernard S. Wostmann, J. R. Pleasants, and B. S. Reddy, Department of Microbiology, Lobund Laboratory, University of Notre Dame, Notre Dame, Ind. 46556

D. C. Anderson, Department of Psychology, Lobund Laboratory, University of Notre Dame, Notre Dame, Ind. 46556

Vitamin B_6 Metabolism in Man

Not only is it important to develop more definitive methods of assessing vitamin B_6 nutriture in persons of all ages, but more precise means of measuring the vitamin B_6 requirement are needed.

A study recently completed demonstrates the forms of vitamin B_6 that are excreted by man with an intake of 1.66 mg daily. Under these conditions the B_6 excreted is made up of 2/3 pyridoxal and 1/3 pyridoxamine. With a decrease of intake to 0.16 mg per day, the urinary vitamin B_6 decreased rapidly. There appears to be a specific effect of such depletion on the excretion of cystathionine and other methionine metabolites.

Continued studies will investigate the vitamin B_6 relationships during pregnancy and during ingestion of oral contraceptives where abnormal tryptophan metabolism is not an accurate indication of vitamin B_6 deficiency in women.

Investigator: Hellen Linkswiler, Department of Nutritional Sciences, College of Agriculture and Life Sciences, University of Wisconsin, Madison, Wis. 53706

ARCTIC ECOLOGY

The subprogram on arctic ecology is sponsored jointly by the United States and Canada and will be concerned with a series of Eskimo communities. It will consist of the following phases:

- Clinical examinations for signs of specific deficiencies (serum iron, hemoglobin, serum proteins, blood levels of vitamin C, folic acid, vitamin B_{12}, and serum lipids)
- Estimation of caloric intake by major food types and seasonal variations (dietary histories, diet analyses, 24-hour urinary nitrogen, and excretion)
- Use and management of local food sources, distribution of food in the community, and type of food brought into the community

The subprogram is being prepared by H. E. Sauberlich, U.S. Army Medical Research and Nutrition Laboratory, Fitzsimons General Hospital, Denver, Colo. 80240, and G. H. Beaton, University of Toronto, Toronto, Canada. Preliminary steps in the preparation are supported by the Medical Research and Development Command, U.S. Department of the Army.

Nutrition Survey among Eskimos of Wainwright, Alaska

This nutrition survey was conducted during January 1969 in cooperation with F. A. Milan, principal investigator of the ecological study. Its purpose was to determine the nutritional status of Eskimos in the village of Wainwright, which is the northernmost village of the United States, 90 miles from Barrow and 300 miles north of the Arctic Circle.

The Wainwright population is 350 (52 households). The median age of males is 14.5 years, compared with 30.4 years for the male population of the United States as a whole. Twenty-seven percent are less than 6 years of age. Blood and urine samples were obtained on one third of the population. Other appropriate observations were made on the total population and its food resources, food practices, and health services.

Blood samples were analyzed for hematocrit, hemoglobin, total serum proteins, the water-soluble vitamins, calcium, and nitrogen.

Evaluation of the data obtained indicates that the most significant nutritional problem was anemia. This appears the result of an inadequate intake of dietary iron. The subjects studied had adequate serum protein levels, and excretion data indicated adequate levels of water-soluble vitamins. Also, urinary nitrogen and calcium were quite high, indicating adequate dietary intakes of protein and calcium.

The schoolchildren were provided a school lunch each day, supplemented with vitamin tablets to provide fat-soluble vitamins. The school has excellent facilities for preparing and serving the lunches.

A cooperative store provides significant amounts of calories and nutrients for the village. Supplies are brought in by boat once a year, usually in September, and are adequate for most of the year. Items that provide ascorbic acid were found to be in good supply.

It appears that Wainwright Eskimos are able to maintain themselves in a generally acceptable nutritional state despite their harsh environment and limited resources.

Investigators: H. E. Sauberlich, W. Goad, and Y. F. Herman, U.S. Army Medical Research and Nutrition Laboratory, Fitzsimons General Hospital, Denver, Colo. 80240

F. A. Milan, Arctic Health Research Center, U.S. Public Health Service, College, Alaska 99701

P. Jamison, Department of Anthropology, University of Wisconsin, Madison, Wis. 53706

Chronobiology

The ubiquity and importance of biological rhythms have become apparent during the last two decades. Methods for detection, quantification, and analysis of rhythms have been developed in the last decade.

The rhythms of the heart, the brain, and respiration are taken for granted. Other more subtle rhythms of circadian (about daily) frequency have been discovered. Body temperature and work fitness are examples of variables that follow a circadian rhythm.

Circadian rhythms are often assumed to be caused by eating or work habits or other schedules. Studies have demonstrated that man, other animals, and plants continue to display circadian variations in the absence of known periodical changes in the environment.

Franz Halberg, Department of Pathology, University of Minnesota, is Program Director.

OBJECTIVES

Objectives are:

- To develop a better definition of health by quantifying normalcy according to rhythmometric criteria
- To measure the effects of shift work and transmeridian flights on body rhythms
- To diagnose maladaptation or early illness by rhythmometric analysis

RESEARCH PLANS

RHYTHMOMETRY STANDARDS

Comparable data will be obtained on selected human body rhythms. Variables selected are body temperature, pulse, blood pressure, certain performance tests, and various aspects of the urine (excretory rate, volume, sodium and potassium content, and the concentration of 17 hydroxycorticosteroids). Priority measurements include body temperature, performance, and urinary sodium and potassium. Standard methods of measurement are used. Measurements on healthy volunteers are taken while the subjects are under normal conditions for their culture.

PHASE SHIFTS

Phase shifts of rhythms will be evaluated on healthy volunteers. Body rhythms will be measured first under normal conditions and then after intercontinental flights. A control group will take flights of the same duration but will circle above the point of departure. These studies will be made on persons who have been subjected to conditions routinely experienced by airplane crews and passengers, and the results will be compared with earlier findings, which suggest that delays of rhythms occur more rapidly than advances. Changes in mental and circulatory performance will be determined. Similar studies will be made on the effects of changes in work routine.

OTHER STUDIES

Projects concerned with body rhythms in cancer chemotherapy, psychiatry, and other areas of clinical medicine have been undertaken.

Additional studies are concerned with shift-work monitoring and arctic chronobiology.

RESEARCH PROGRESS

RHYTHMOMETRY STANDARDS

Circadian rhythms of heart rate, oral temperature, and urinary hydroxycorticosteroids and potassium excretion have been measured by investigators in various parts of the world. The fact that all investigators found similar rhythms indicates that the data can be used as clinical standards. (See Halberg *et al.*, 1969, in the appended list of publications.)

PHASE SHIFTS

A study of the effects of transmeridian flights on man shows that the adjustments that follow flights from east to west differ, in the same persons, from those that follow flights from west to east. (See Halberg, 1969, in the appended list of publications.)

OTHER STUDIES

Acrophase charts have been prepared for shift-work monitoring and for possible clinical use. (See Halberg *et al.*, in press, in the appended list of publications.)

Data on arctic chronobiology in relation to human performance on odd schedules have been collected. Additional data on arctic chronobiology were collected for the IBP study of Eskimos (see p. 65).

APPENDIX: PUBLICATIONS

Bohlen, J. G., F. A. Milan, and F. Halberg. In press. Circumpolar chronobiology. Proc. IX Int. Cong. Anatomists, Leningrad, 1970.

Halberg, F. 1969. Chronobiology. Annu. Rev. Physiol. 31:675–725.

Halberg, F., W. Nelson, R. Doe, F. C. Bartter, and A. Reinberg. In press. Chronobiologie. J. Eur. Toxicol.

Halberg, F., J. Reinhardt, F. Bartter, C. Delea, R. Gordon, S. Wolff, A. Reinberg, J. Ghata, H. Hofmann, M. Halhuber, R. Günther, E. Knapp, J. C. Peña, and M. Garcia Sainz. 1969. Agreement in end points from circadian rhythmometry on healthy human beings living on different continents. Experimenta 25:107–112.

APPENDIXES

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Appendix A

Organization of the IBP in the United States

More than 3 years of planning and coordinating activities and 1 year of research sponsored by the U.S. National Committee have culminated in a sophisticated scientific plan of integrated and coordinated research programs. The IBP organization now consists of:

- Executive Committee
- Directors of integrated research programs
- Directors of coordinated research programs
- Directors of biomes
- Directors of key subprograms

This membership constitutes the U.S. National Committee for the IBP.

EXECUTIVE COMMITTEE

W. Frank Blair, *Chairman*
T. C. Byerly, *Vice-Chairman*
Stanley I. Auerbach, *Vice-Chairman*
Paul T. Baker
Everett S. Lee
Frederick Sargent, II
Frederic H. Wagner
Donald S. Farner (*ex officio*)

INTEGRATED RESEARCH PROGRAMS

Environmental Component

Stanley I. Auerbach (Deciduous Forest Biome)
W. Frank Blair (Origin and Structure of Ecosystems)
Jerry Brown (Tundra Biome)
Richard C. Dugdale (Biological Productivity in Upwelling Ecosystems)
Stanley P. Gessel (Coniferous Forest Biome)
David W. Goodall (Desert Biome)
Harold Mooney (Mediterranean Scrub Project)
Dieter Mueller-Dombois (Island Ecosystem Stability and Evolution Subprogram)
Howard T. Odum (Tropical Forest Biome)
G. Carleton Ray (Marine Mammals)
Otto T. Solbrig (Structure of Ecosystems Subprogram)
George M. Van Dyne (Grasslands Biome)

Human Adaptability Component

Paul T. Baker (Biology of Human Populations at High Altitudes)
William S. Laughlin (International Study of Circumpolar Peoples)
Frederick A. Milan (International Study of Eskimos Subprogram)
James V. Neel (Population Genetics of South American Indians)

COORDINATED RESEARCH PROGRAMS

Environmental Component

William S. Benninghoff (Aerobiology)
John L. Creech (Conservation of Plant Genetic Materials)
C. C. Delwiche (Biology and Ecology of Nitrogen)
Carl B. Huffaker (Biological Control of Insect Pests)
George Sprugel, Jr. (Conservation of Ecosystems)
Forest Stearns (Phenology)

Human Adaptability Component

C. Glen King (Nutritional Adaptation to the Environment)
Everett S. Lee (Biosocial Adaptation of Migrant and Urban Populations)

Appendix B

Officers and Members of the Special Committee for the International Biological Program

OFFICERS

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Prof. F. Bourlière (France)

Vice-Presidents

Prof. W. F. Blair (United States)
Sir Otto Frankel (Australia)
Academician I. Málek (Czechoslovakia)
Prof. H. Tamiya (Japan)

Scientific Director

Dr. E. B. Worthington (United Kingdom)

MEMBERS

Representing ICSU and member unions of ICSU

ICSU	Prof. D. Blaskovic (Czechoslovakia)
IUBS	Dr. Arthur D. Hasler (United States)
IUB	Prof. M. Florkin (Belgium)
IUPS	Prof. P. O. Åstrand (Sweden)
IGU	Prof. C. Troll (Federal Republic of Germany)
IUPAB	Dr. A. R. Gopal-Ayengar (India)
IUNS	Prof. C. G. King (United States)

Convenors of sectional committees

PT	Prof. J. B. Cragg (Canada)
PP	Academician Málek (Czechoslovakia)
CT	Mr. E. M. Nicholson (United Kingdom)
PF	Prof. G. G. Winberg (Union of Soviet Socialist Republics)
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UM	Dr. G. K. Davis (United States)

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IUCN	Prof. J. G. Baer (Switzerland)
IUAES	Prof. J. Hiernaux (Belgium)
IAHB	Prof. J. Hiernaux (Belgium)

Representing scientific committees of ICSU

SCAR	Prof. G. A. Knox (New Zealand)
SCOR	Dr. O. H. Oren (Israel)

Elected members

Prof. W. F. Blair (United States)
Dr. A. E. Boyo (Nigeria)
Prof. B. E. Bychowsky (Union of Soviet Socialist Republics)
Prof. F. di Castri (Chile)
Sir Otto Frankel (Australia)
Dr. R. W. J. Keay (United Kingdom)
Prof. G. Montalenti (Italy)
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Dr. F. Salzano (Brazil)
Prof. B. R. Seshachar (India)
Dr. H. Tamiya (Japan)
Prof. H. Thamdrup (Denmark)
Prof. C. A. du Toit (Republic of South Africa)

Appendix C

Countries Participating in the IBP, with Chairmen of National Committees

Argentina	Prof. O. Boelcke
Australia	Sir Otto Frankel
Austria	Prof. W. Kühnelt
Belgium	Prof. P. Duvigneaud
Brazil	Prof. A. Cury
Bulgaria	Prof. I. Pashev
Canada	Dr. T. W. M. Cameron
Ceylon	Prof. B. A. Abeywickrama
Chile	Prof. Dr. F. di Castri
China, Republic of	Dr. Jong-Ching Su
Colombia	Dr. Luis Eduardo Mora
Congo, Democratic Republic of the	Mr. J. Ileo
Czechoslovakia	Prof. I. Málek
Denmark	Prof. H. M. Thamdrup
East Africa	Prof. W. B. Banage
Kenya	Dr. R. S. Odingo
Tanzania	Mr. A. S. Msangi
Uganda	Dr. G. H. Kiwauwa
Ecuador	Dr. M. Acosta-Solís
Finland	Prof. H. Luther
France	Prof. Th. Monod
Germany, Democratic Republic of	Prof. H. Stubbe
Germany, Federal Republic of	Prof. H. Ellenberg
Ghana	Dr. A. J. E. Bucknor
Greece	Prof. G. Athanasiades Novas
Hungary	Prof. J. Balogh
India	Prof. B. R. Seshachar
Indonesia	Dr. O. Soemarwoto
Ireland, Republic of	Mr. P. M. McDonnell
Israel	Prof. M. Evenari
Italy	Prof. C. Barigozzi
Japan	Prof. H. Tamiya
Korea, Republic of	Prof. Yung Sun Kang
Malawi	Dr. N. P. Mwanza
Malaysia	Enche K. D. Menon
Mexico	Dr. A. Ayala-Castañares
Netherlands	Prof. G. J. Vervelde
New Zealand	Prof. G. A. Knox
Nigeria	Prof. C. I. O. Olaniyan
Norway	Prof. R. Vik
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Peru	Prof. Hernando de Macedo
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Poland	Prof. K. Petrusewicz
Rhodesia	Prof. E. Bursell
Romania	Prof. N. Salageanu
South Africa, Republic of	Prof. C. A. du Toit
Spain	Prof. A. Carrato
Sweden	Prof. C. O. Tamm
Thailand	Lt. Gen. P. Salvidhannidhes
Tunisia	Mr. El Fekkih
Union of Soviet Socialist Republics	Prof. B. E. Bychowsky
United Arab Republic	Prof. H. Said
United Kingdom	Prof. A. R. Clapham
United States	Prof. W. F. Blair
Uruguay	Dr. C. Estable
Venezuela	Prof. F. H. Weibezahn
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Yugoslavia	Prof. Dj. Jelenic

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